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THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

PROCEEDINGS.

SESSION 1902—1903.

VOL. XVIII.

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CONTENTS OF VOL. XVIII.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

SESSION 1902—1903.

The First Meeting of the Session was held at The Institute, Dudley, on Saturday, the 18th October, 1902.

THE PRESIDENT (Mr. WALTER SOMERS, J.P.) presided.

The minutes of the Annual Meeting, held in April last, and of the Visit to Coventry, were read, adopted, and signed.

Messrs. H. L. Evers, George Hadley, Alfred E. Nurse, and Alwyn Howarth Thwaite were elected members of the Institute.

THE PRESIDENT: I welcome you here for the new Session, and I hope that we shall have good attendances and some able papers during the winter; and I have no doubt we shall have some very useful discussions. I accord you a most hearty welcome to our Institute.

THE PRESIDENT then delivered his inaugural address, as follows:—

ADDRESS BY THE PRESIDENT

(Mr. WALTER SOMERS, J.P.)

On being asked to become your President for the second year, I did not think I should be called upon to make a second Presidential Address, and, being a very busy man, my difficulty will be in making my address interesting. However, as I have lately made a visit with the Iron and Steel Institute to Germany, I will relate my experiences in that progressive country, and try to give a little information as far as my experience goes.

When the Iron and Steel Institute was invited to hold its Annual Meeting at Dusseldorf, I at once made up my mind to attend, and see if I could find out how it was that we were being driven out of our home markets. Accordingly I accepted the very kind invitation of the North German Lloyd Co. to go by their splendid ship the "Crown Prince William," to Bremen. I cannot help stopping to say a word of appreciation of the arrangements made by the Secretary of the Iron and Steel Institute, Mr. Bennett Brough, and his very able assistant, Mr. Lloyd, who upon all occasions gave us most valuable assistance.

We started from Plymouth at five o'clock on Monday morning, September 1st, and after a most enjoyable trip we landed at Bremen Haven on Tuesday mid day. Everyone expressed their great appreciation of the most kind hospitality of the North German Lloyd Co We were then taken on to Dusseldorf by a special train.

On Wednesday morning the meeting commenced, and in the afternoon the Exhibition was visited, where we saw the wonderful exhibits of our friends the Germans.

To mention all these exhibits would take a long time, but I will tell you of a few.

First of all, the firm of Fried Krupp has a very large building full of their own manufactures. No doubt the most striking of these manufactures was a large armour plate, weighing 106 tons, measuring 43ft. 2in. long, 11ft. 2in. wide, and 12in. thick; there was also a large plate weighing nearly 30 tons, and measuring 88ft. long, 12ft. wide, by 1½in. thick; then we came to a long crucible steel shaft, hollow, made from an ingot 80 tons weight—and to give you an idea of the magnitude of

he crucible steel works, this ingot was cast from 1,768 crucibles, the operation occupying 490 men during half an hour—this ingot was nearly 13ft. long by 6ft. in diameter, and was drawn out under the 5,000 ton press at Essen, to 145ft. long; afterwards a hole 5in. diameter was bored through the shaft, and the piece that was trepanned out was to be seen placed over the shaft and was about 2½in. in diameter; there it was showing how sound was the forging. We next came to a line of shafting for the North German Lloyd Co.'s new fast steamer "Kaiser Wilhelm II." this was 233ft. over all, and comprised one six-throw crankshaft, in six parts, coupled together, one thrust shaft, five intermediate shafts, and one propeller shaft—weighing altogether 226 tons—all completely finished, bright, and bolted together—really a very fine piece of work. We then came to some fine steel castings for ships, such as stem, stern, and rudder frames, varying in weight from 5 to 40 tons each.

In the centre of the Krupp buildings was a 12in. gun, on central pivoting mounting ready for action; it was 40ft. long and weighed 50 tons. And there were many other guns and exhibits far too numerous for me to mention.

We then proceeded through the Great Machinery Hall, which was a very large building full of the most interesting and expensive machinery of every description, and which would require weeks to go through and examine carefully. We also passed through other buildings containing those exhibits of other firms which were too large to find room in the Great Machinery Hall.

On Thursday many of us took advantage of an invitation to visit different works in and around Dusseldorf; and these works proved to us beyond doubt that the Germans had taken advantage of, and profited by, the lessons learnt from us, say, 20 years before. It is doubtful if we in the same time have made the same rapid progress.

On Friday 150 of us who had been fortunate enough to receive tickets went to Essen. Mr. Krupp invited 150 members, saying he could not accommodate more; we had, therefore, to ballot for these invitations.

We were taken by a special train which was shunted into the works at Essen. Here we were most kindly received, and for two hours we were taken through the works and shown as much as was possible to see in that time. First we saw an armour plate mill where a very large armour plate, 12 inches thick, was being rolled; then the steel works, and the 5,000 ton press at work on a 50 ton ingot making a large gun. We then passed through the turning shops, and when I tell you that there was a large lathe weighing 485 tons, with bed 166ft. long, and other large lathes, planing, slotting, and other machines, too numerous to mention, you can readily understand the interesting time we spent. After seeing the rolling machines, we adjourned to Mr. Krupp's private

hotel in the works to accept his hospitality in the shape of a very good lunch, which I can assure you we much enjoyed after our long walk. After lunch we were driven in carriages, supplied by our host, to the gun practice ground, where we saw a grand exhibition of gun practice. We were afterwards taken through the crucible shop, which was an immense place. At four o'clock we left by a special train for Mr. Krupp's house at Hugel, a most palatial residence. The greatest charm of this was the hearty welcome accorded to us by Mr. and Mrs. Krupp and their two daughters. Every guest was made to feel most thoroughly welcome, and I am sure we all realised that although Mr. Krupp was from a business point of view one of the wealthiest men in his country, his worldly riches seemed to us as nothing in comparison with his wealth in the true characteristics of a gentleman and perfect host.

One of the chief things that struck me about the German trade was the rapidity of their progress and enterprise. One of the managers of some works I went to see remarked to me, "You Englishmen came here 15 to 20 years ago to show us the way to do things, but now you come here to learn. You have been standing whilst we have been advancing rapidly." Although with some reluctance, I could not but realise that what he said was, to a great extent, correct, and I made up my mind there and then to get what information I could as to how this came about. The only conclusion I could form after careful study and observation was, that our want of proper education was at the root of it. We are undoubtedly allowing the Germans to get ahead of us in education; I do not mean simply our working men, but in the education of all classes. For instance, a student in our country goes to the University or Technical School, and there he answers questions on paper; but where is his practical knowledge? In Germany, a student not only answers questions on paper, but he receives practical tuition and is provided with every facility for practically illustrating his theoretical knowledge. We are, perhaps, not sufficiently endowed with plodding ability, and our country does not offer us the same facilities for stimulating this ability as does Germany. Germany appears to be fully alive to the fact that to make a child or man retain and use theoretical knowledge he must be educated by practical demonstrations. For example, some years ago we had about the same number of chemists in this country as they had in Germany, and ours were superior and had passed higher standards; this has now changed, the Germans have three times as many chemists as we have, and many of their men have passed higher standards than ours. This is owing to the greater facilities they have for practical demonstration, which leads them on to greater researches and fosters their ambition. Theoretical knowledge enables them to recite theories, but it does not help them to solve problems in a laboratory. Theory is not the vital part of chemistry, we must have more practical knowledge, and our technical schools should be better

equipped for this, and in addition to our technical schools we should have industrial schools, where pupils can illustrate their theoretical knowledge.

Another instance is that our Patent Laws are not as they are in Germany. If a German has a good idea and wishes to work it out, he can have it tried privately and confidentially by a proficient committee, and if there is anything in it the man receives some benefit. It is not so in this country, we have not, unfortunately, this advantage; here a man who has an idea must work it out and finance himself; and if he has not the money to do this the idea never comes to light. It is impossible to estimate the number of ideas that are so lost to our country.

I was also struck by the fact that the German workman seemed so capable of thinking for himself, it was noticeable in the fact that on all occasions he uses his brains to save himself physical exertion, and he does this to a far greater extent than our English workmen do.

I should like to take this opportunity of again impressing upon South Staffordshire the importance of a waterway to Liverpool, London and Gloucester, as there is no doubt the excessive charges and arbitrary conduct of our Railway Companies very considerably handicap the trade of the Midlands and makes it impossible for us to compete with foreigners, whose rates are so much lower. Here, again, Germany has a great advantage over us, and so great is that advantage, that—as an instance—manufacturers in the middle of Germany can actually deliver goods to the North of England at a less rate than we in South Staffordshire can deliver to the same place. This is owing to the State controlling the Railways in Germany; and when one realises our disadvantages in England we must surely feel that the sooner the State controls our railways the better it will be for us and the encouragement of the full development of the trade and resources of the country.

I should have liked to have written a very much longer address, but I have not been well; but I thought, perhaps, that what I have laid before you might open up discussion, and I should, therefore, now be glad to hear any expression of opinion upon this subject of foreign competition and of equipment. It is no use our trying to get past the fact that there are certain systems and regulations in Germany by means of which all concerned in production—employers, managers, and the workmen alike—seem to act together with better results than in this country. I was in an engineering works when a bell went at 12 o'clock. They have one and a half hours there for dinner, and the moment the bell rang each man came across to where there was a long trough, pulled off his overalls, reached his soap and towel, and washed and made himself presentable before he went into the dining hall belonging to the works. I said to our guide, "Whatever do they do with one and half hours for dinner?" He replied, "I will show you what they do." In

about half an hour they had done their meal, and came out of the dining hall, and went a little way down the street, to where there was a large institute. Some turned into the laboratories, some for drawing, some for reading, some for one thing and some for another. They turned in not by two and threes or in fours and fives, but by the score, and occupied themselves by improving their minds. With regard to both our working men and our educated classes—that is. our so-called educated classes—it may be said that we do not make enough of the advantages we possess. If those opportunities were taken advantage of, depend upon it the Government and the various authorities in different parts of the kingdom, would awake to the fact that there must be something more. Until our technical schools are made use of to the extent they ought to be, we cannot expect public authorities to provide such facilities as they have in Germany.

Professor THOMAS TURNER: I am sure we have been interested in hearing what our President has said to-night, and that we shall sympathise very much with him in the ill-health from which he has recently been suffering, and the circumstances through which he has passed; and we have to thank him the more, therefore, for being here to-night and for reading us such an address as that to which we have listened. I had the pleasure of going over to Dusseldorf during the summer, and I believe there are several other members of our Institute who were also in Germany, and I say I agree with what the President has said. It was 10 years since I had been to Germany before, and even then—in 1892—I was very much struck with the material progress made since the Franco German War, particularly in Southern Germany. In 1892 there was every indication of new industries and new works. But when one went back again again after ten years it was very striking indeed to see the increase in population, the additional works which had been put up, the increased size of the works, and the new processes which had been introduced. One could not help contrasting our Black Country at home and seeing how comparativety stationary we had been. I did not have the opportunity to visit Messrs. Krüpp's Works. But on that day several members of our Institute went to the Hoerde and the Hörsch Works. The latter were splendidly laid out all on the square, everything being quite straight through, thus allowing of the handling of material in the simplest and readiest manner. I was driving through quite a thriving populous district—with a good hotel, large shops, well-built houses of four or five storeys, built apparently on the "flat" system—with the managing director of the works, and he explained to Mr. Cooper, of the North Eastern Steel Company, who was in the same carriage, that he remembered that neighbourhood "when that house there" (to which he pointed) "was the only house within sight from where you are at present." Now that whole district, containing over 100,000 inhabitants has all sprung up within the recollection of that

managing director. That gives you an idea of how the neighbourhood on the Rhineside is progressing. Of course we remember something like that happening in Middlesboro', but though the rise of that town may well be regarded as remarkable, yet Middlesboro' has not the population to which I refer; and this German town has sprung into existence since Middlesboro' became an important industrial centre. A great deal of the German progress has been due to the fact that they had trained men waiting ready for employment. Now we are trying to do a great deal in England by our evening technical schools, and there is no doubt these are doing—and have done—a very important work; but after all we must not put the evening technical schools of our country in comparison with the universities and technical high schools of Germany. In Germany, a boy by the time he is 14 has done his primary course. He then goes to a thorough secondary school and takes a high course there, so that he leaves with a good knowledge of mathematics and a fair knowledge of technics. And then he starts a four years' course of higher education, and does not begin to earn money till he is two or three and twenty, and even then you have to take out one year for Army service. These men have therefore a considerable knowledge both of theory and of practice, for, taking into consideration the length of time in the schools, the instructors are able to teach more than we teach in England. Take the three years' course in England. You begin with a young student who has been learning classics and possibly a smattering of one modern language, but not much mathematics. He comes to your college and wants to take a course of study for which he is quite unprepared. At the recent matriculation examination of Birmingham University over 60 entered and only 16 passed. So three-fourths were not able to pass the entrance examination, which is really not a severe one. Now how can a teacher build upon such a foundation? In America it is the same as in Germany. The men take not only theoretical but also practical courses, including filing, turning, fitting, and moulding, all of which is done in the shops which form part of the higher technical school training. Now if we can get people to follow in the lines of our competitors, in the way of giving a longer course of training to the young men who are in time to become our leaders of industry, we shall do a great deal of good for our country. But it is an uphill fight, and we shall, I am afraid, have to be content for some time with a small number of students, The other day Professor Hanover, from Copenhagen, visited the University at Birmingham. He is Professor of Mechanical Technics, which is a branch of the engineering profession which is not taught in this country. He asked us, "How many engineering students have you?" I replied, "Our engineering is a strong department, we have between 100 and 200 engineering students." "Is that all?" he said, "Why, I have got over 500 in Copenhagen." Now those are students who are taking a preparatory course before entering works. Yet Denmark itself has a

considerably less population than the Black Country. We know what the Danes have done in dairying, and I suppose they are trying to do the same in engineering. There is no doubt that just as the Germans laid their plans for the Franco-German war long before it happened (for the campaign was fought almost exactly as Von Moltke had worked it out beforehand), so the Germans have had their present policy of industrial development previously mapped out, and they have prepared their men for the present international commercial warfare during a course of training extending over several years. It is only by training the future leaders in that thorough university manner, and then putting under them *other* men who have been trained in our secondary and technical schools, that we can hope to compete with our friends across the water. Of course they have good waterway communication in Westphalia, and good iron ore; but a large proportion of their ore is imported, and the Rhine was very many years before it was developed for water carriage. In fact, for a very long while it was almost valueless for purposes of trade until the present great quays and havens were built. The Germans have made the Rhine the excellent waterway it is to-day. The water truly was there, but everything else has had to be made, and we cannot but admire the energy and foresight which has led to such satisfactory results.

Mr. Walter Jones: We are much indebted to our President to-night. He has given us a short address, but it is full of very salient points. For instance, he touched upon the nationalisation of railways. I don't know whether we are ripe for that, or prepared for it, but something of the sort wants doing. He also touched upon water communication, and those gentlemen who are engaged in heavy industries will endorse everything he has said in that direction. There is no doubt the heavy industries in the Midlands are greatly handicapped for want of better communication with the shipping ports. Again, he referred to the Patent laws. I think the Patent laws in England are a disgrace. Facilities for patents in most other countries are far and away before the British Patent laws. In America they make a search for you, and also in Germany. Here you have to make your own search, and often the result is that you patent the same thing that someone else has patented previously. They take the fees and you have to take all the risks. As far as education is concerned, I mean higher grade education, theoretical and practical, we have much to learn from the Germans. I was much struck with that part of the address about the employers making provision for washing, and also providing an institute. I mentioned the same thing—about the washing—to some of my men this week, and they laughed at the idea. It appeared to them a ridiculous suggestion. But this seems to be done to a large extent in some of the industries of America. The idea of the Americans as regards hours, wages, and their general arrangements, is to get the greatest possible amount of work out of each individual in the shortest time, and to get them to take the

greatest amount of interest in the work. But I think it is the exception for the English workman to take any interest in his work at all. They look for the Saturday night and that is all. I should like to see more consideration on the part of employers for the workmen. I heard the President make a remark the other night to the effect that during the time he was on the Continent, he did not see a drunken man. It is not because they do not drink any beer—I think they drink more than in this country—but it is of a light kind, and a good many of our work-people suffer from having too many facilities for getting drink stronger than they need. We are very much indebted to our President for giving us this paper. It must have been highly interesting to see those large German works. Even if we feel the Germans are taking the lead, I don't think we shall begrudge them; there is plenty of room for them to live as well as ourselves. And it is open to us, if we wish to do so, either to follow in their footsteps or to even excel them later on.

Mr. H. PARRY: I take this opportunity, Mr. President, of thanking you for having brought before us this interesting paper as your second inaugural address. When a gentleman like yourself is elected for the second time to the office there is no doubt of the respect and esteem the Institute has for him. I feel that the question of technical education is one which wants more thoroughly bringing home to the British people. But unfortunately, in this country, whenever the subject of education is brought forward, the "religious" question comes in. I don't know whether it is excess of religion, or the want of it, that leads to educational progress in Germany; but it seems to go forward better there than here. The German workman seems to be thoroughly acquainted with the practical and theoretical aspects of his work, and to be able to answer intelligently any question that may be put to him about it. But there is another matter, and that is that sufficient attention is not paid to commercial education in this country. The Germans are not only beating us in their trades, but their commercial representatives are ousting us from our own markets. I fancy a little more enterprise is wanted on the part of the capitalists of this country, if better plants are required. The career of such men as Mr. Andrew Carnegie and Mr. Arthur Keen, shows that technical education is not all that is needed for success in trade, and the same may be said of some prominent local gentlemen; I mean they are not men who owe their position to technical knowledge, but mainly to good commercial training, and if the educational authorities of this country take commercial education in hand as well as technical instruction, I think we shall be able to more than hold our own.

Mr. H. SILVESTER: I desire to associate myself with the previous speakers as to the pleasure it has afforded us to listen to your experiences in Germany. When I was in Germany, what most struck me was the orderliness of the works. Everything was extremely clean and neat,

And I was impressed also with the courtesy and good feeling that appeared to exist between the men and the managers. I was talking about this feature to some of the managers, who attributed this characteristic to the military training which every man receives. Reference has been made by Mr. Parry to the commercial side of the question of German competition. And although we have heard a good deal about the excellent modern German plants, these fine works are not always able to return a dividend.

I visited some large works laid down on American lines, and from the mills down to the chemical laboratory everything was of the finest. I have seen a few works laboratories, but in this country I have never met with anything so complete as what I saw in Germany. The capital of the company, however, had, I understand, been halved, and the idea one got was that it was possible to make the tool too elaborate, and consequently, too costly for the work that it was required to do. There is no doubt that the higher educational system in Germany is more complete than our own. In England, perhaps, we have not yet got a right appreciation of what technical education is, and what technical education will do. A man is not technically educated who has attended a course of evening science lectures, and it is beginning to be understood that three or four years at a college will not enable a man to solve at once every difficulty that may crop up in the works that he enters. In Germany the association of a thorough science education with practical works' experience, seems to be much more common than in this country, and in this respect we might learn a good deal from the Germans.

Mr. H. B. Toy confirmed the remarks of the President and previous speakers as to the way in which the German works were laid out, and instanced as an example of the neatness with which the works were kept, that it was no unusual sight to see flowers planted round the walls of foundries.

Mr. John Fellows: I have listened with very great pleasure to the President's address, and I think that the most painful thing about it is that the Germans send their productions over here and undersell us, not by a shave but by a very large sum, and the question is—how do they do it? Many of us recollect the address of Mr. Ebenezer Parkes on American competition. At the conclusion of his address he stated most emphatically that the Americans were not beating us through one cause only but for many causes, and he especially enumerated some 14 or 16 items which were factors in the case. After hearing the President's address to-night, and the remarks from the various speakers who have followed, it is quite patent that this German competition is not owing to one circumstance, but to a number. Wages there are considerably lower than here. The hours are considerably more. And, as has been said, the works are very well laid out, and there seems a good deal of method

about their works' arrangements, and about the manner in which the labour is performed. Probably that is owing to the military training of the nation. If you go into an ironworks in England you see piles of material in all directions, and a lot of it is being buried by other material; but nothing of that sort was in evidence in Germany. The remarks made by Mr. Toy about geraniums growing under the foundry wall gives you an idea of the clean, swept-up, orderly appearance of the whole works. Their works are built on the square. It seemed as though land was no object, there was such a large amount of room, and the arrangements really seemed in every respect first-class. Then again, they seemed to excel in their electrical appliances. I agree with the President in his remarks about railway rates and the benefit to be derived from water carriage. You see a little steam tug pulling half a dozen boats down the Rhine, taking immense cargoes from Dusseldorf to Rotterdam and other ports, and these cargoes are handled very expeditiously and cheaply, and are soon put on ocean-bound steamers; and, as the President says, goods will come from Dusseldorf to Manchester almost at the same rate as we can send them from Staffordshire to Manchester. Their mining operations seem to be carried out on scientific lines and on a very large scale The Germans seemed very pleased to see us and to show us the works; and they seemed fully conscious that they had nothing to fear.

Mr. W. Brooks (Vice-president) : Unfortunately I have not had an opportunity of going to Germany; but after hearing of the works and of the methods employed, the wonder to me is that we in South Staffordshire are able to exist at all. Our great misfortune is that we are working with old tools and the old machines. If our capitalists would lay out works upon modern lines and put Englishmen in to work them, I think we could get as good results out of them as anyone. However well you may instruct the youths of this country, if you turn them into badly laid out and poorly equipped works, you can never expect to get good results. Our President is a long way in advance of many of the employers of the district. Yet he found his visit very interesting. I propose that the best thanks of this Institute be given to our President for his very interesting address.

Mr. James Piper seconded the vote, which was carried with acclamation.

The President: I thank you very much for the compliment you have paid me, and I am not afraid to say that I look upon this Institute as a very powerful instrument in the way of working up our trade. The general question of British progress in face of foreign competition depends, as I have said several times here, upon the managers of works and upon their thought and careful study as to the best way to economise labour and to carry on the various works. I hope I have not conveyed the impression that our position to-day as a country is the fault either of workmen or of managers; but I say this, that commencing with the

masters (I am one myself) and going on to the managers and then to the men—that taking us altogether we have not had the means at our disposal, neither masters, managers, nor men, to be educated up to the standard of Germany. Then again I don't think there is the same spirit here that there is in Germany. I heard myself that some of the German works did not pay. Well, of course, there is such a thing as overdoing it. There are many articles in this country which are made very cheaply. Take for instance, rigging chain. Now chains are made very cheaply by hand, yet people have put down machinery for making them. The interest on the outlay at 5 per cent. would more than cover the cost of making the chain manually. In such a case it is absurd to put down expensive plant; it is over-doing the subject of works improvement. There is no doubt that more scientific training is needed. How many of the employers in South Staffordshire could walk in at Birmingham University and give Mr. Turner a scientific explanation as to steel making or ironmaking. Employers in England do not know things for themselves so they have to rely on others. In Germany a master has not to call up his manager to give you information. The principals of the various works are themselves scientifically instructed. I must plead ignorance to a great extent myself, but still I have made as much use as possible of the little knowledge I was able to get hold of, though perhaps at school I did not make the most of my opportunities. Now we come to the managers. There ought to have been facilities long ago for every roller and shingler to go to a technical school and get a practical and theoretical knowledge of what he is doing. Where do you find such a school? An Institute like this is a great factor. Everyone engaged in iron production should belong to an Institute like this, where we can discuss various matters connected with the iron trade. A man who works at the rolls may, in this country, work his way up to the position of manager, and this has often been done; but what if he had had an education as well? He might with that advantage have been the cleverest man of the day. But he has not had the opportunity. Then we come to the workman. Until lately, unfortunately, there was no such thing as a technical school for a workman to go to. There is another point. Our children at ordinary schools must be taught to think originally. When boys go into Board Schools and National Schools as very little ones, they are taught by means of object lessons, but when the boy gets a little bit beyond infancy all that sort of thing is done away with and he goes in for sheer grinding. He has perhaps three years of this grinding, until he is sick and tired to death of it. The boy at school ought to be so taught that he will think for himself. What is wanted is not so much "cramming" to get the grant, as to make children pleased to go to school instead of being pleased to run away. The moment you get into the German schools and institutes you are attracted; it is interesting to walk round them; and, of course, the more attractive a school is, the better

for the students. They get plenty of scholarships, because the Emperor is particularly interested in educational matters. He also takes a personal interest in the nation's manufacturing progress. I don't think Englishmen are going to be cast down and let the Germans ride over them. I must say that I am not, anyhow. I went there to find out why it was they ran us so closely, and I said to my people when I came home, "It is no good my telling you what I have seen. Now on Monday off you go to see for yourselves." So I sent two of my foremen for a week. When they came back, they said, "If you will find us another tool or two we can do more than they can." I said, "But what can you do with the present machinery?" They replied, "We can do at present everything we saw, and if you will find us a few more tools we will try to go one better." I think that is the way. Let your own people go and see for themselves, and let both sides pull together. If you have not confidence in them, and they in you, it will be a very poor thing for this country. I must say we saw what we did not expect to see, and I hope British manufacturers will profit by it.

We are all very pleased to see our friend Mr. Parry with us to-night after his very serious illness, and I trust he will be with us for many years.

The Second Meeting of the Session was held at The Institute, Dudley, on Saturday, the 29th November, 1902.

THE PRESIDENT (Mr. WALTER SOMERS, J.P.) presided.

The minutes of the previous meeting were read, adopted, and signed.

Messrs. W. H. Danks and George Head were elected members of the Institute.

Professor TURNER then read the following paper :—

SOME NOTES ON A VISIT TO WESTERN PENNSYLVANIA, IN 1902.

By THOMAS TURNER, M Sc., A.R.S.M., F.I.C., Professor of Metallurgy in the University of Birmingham.

As so much has been written in this country in recent years in reference to American practice in the manufacture of iron and steel, from the Special Volume issued by the Iron and Steel Institute, in 1890, to the Report recently published by the British Iron Trade Association; and as several important papers on the subject have already been communicated to this Institute, including contributions by Messrs. Ashton, Farnworth, Head, Pilkington, and more recently by Mr. E. Parkes, M.P., it is perhaps well that some explanation should be given of the circumstances under which the author has complied with the suggestion of your Secretary and ventured to put together some notes on a visit paid to Canada and the United States in the summer of the present year.

The members of the Institute are no doubt aware that an important extension is in progress in connection with the teaching of Applied Science in the University of Birmingham. Large buildings are now being erected on a site which covers upwards of 25 acres, and which is situated to the south of Birmingham, but just within the city boundaries Good progress has already been made with the power station, and the engineering blocks are in hand, while the large central hall has also been commenced. The plans and estimated cost of equipment of the metallurgical and mining block have been approved by the Council of the University, and it is intended that shortly there will be in working operation a metallurgical department on a more complete, extensive, and practical scale than has hitherto been attempted in this country. In connection with the preparation of the plans for this part of the work Professor Redmayne and the Author were instructed to visit certain representative Universities and Technical Schools in Canada and the United States and to report. The visit was necessarily brief, and was chiefly devoted to the special object in view; but the opportunity was taken by Professor Redmayne to inspect certain representative mining operations, while the author visited works in which electro-metallurgical and refining processes were conducted, and also spent a short time in Michigan and Western Pennsylvania. The present notes deal chiefly with the last-named district, the centre of which is Pittsburgh; and no claim is made for either completeness or originality.

It is hoped, however, that as each observer views a thing from his own standpoint, a brief record of what the author saw himself, or heard first-hand from those actually in charge of the works, may, despite any incompleteness or possible inaccuracies, be of some interest to those members of the Institute who have not, as yet, themselves had an opportunity of visiting the Pittsburgh district.

So much has been heard from time to time of the extreme purity and easy reducibility of American ores that it may be well to point out at once that ores of equal purity are to be obtained in this country, and ores too which can be quite as easily smelted in the blast furnace. The important questions, when comparing the two countries, are less those of quality than of quantity and of distance, and we are perhaps apt to attach too much importance at times to the immense mineral resources of the United States and too little to the energy, industry, perseverance, and skill of the people, apart from which all the most bounteous provisions of nature would have been of no avail.

The history of the iron trade of America may be conveniently divided into two parts. In the first, where the processes were as described by such standard writers as Overman or Percy, it was considered essential that all the materials necessary for the manufacture should be found close to the spot on which the metal was to be produced. In this period the plants were small and the total production relatively unimportant. But with the development of the bituminous coalfield of Western Pennsylvania, and the opening up of the iron ore regions of Lake Superior, during the last quarter of the nineteenth century, it has been seen that ready and cheap transport was of greater importance than contiguity of supplies. The enormous quantities of material which were available allowed the question of transport to be dealt in a comprehensive and masterly way, which again reacted on the size, capacity, and output of the works in such a manner that a modern ironworks became a centre to which were collected materials of all kinds, assembled from far distant localities, and at which were to be seen examples of the best engineering practice of the day. It was in this way that the at one time apparently insuperable difficulty of distance led to an enormous expansion of the iron trade in Pennsylvania, and to the erection of immense plants which have served as models not only for the rest of the United States, but also in many important respects for the whole of the civilised world.

At the present time, in round figures, something like four-fifths of the iron ore raised in the United States is obtained from the Lake Superior region, the districts being in order of output as follows:—Mesaba, Memominee, Marquette, Gogebic, and Vermillion. Of the total output of Lake Superior ore nearly one-half is obtained from Mesaba, the production of which is steadily increasing. The greater part of this Mesaba ore is obtained by steam shovels in open working, and is of a dirty

brown earthy colour, not unlike good garden soil in appearance, and so finely divided that about 30 per cent. of it will pass through a 100 mesh sieve. In Mr. Head's paper the proportion of iron contained in the various ores was given as follows :—

Mesaba,	average of 12 Mines	63·32	per cent.
Memominee	„ 6 „	56·29	„
Marquette	„ 9 „	61·52	„
Gogebic	„ 2 „	60·72	„
Vermillion	„ 6 „	65·01	„

which would give an average of about 61·35 per cent. of metallic iron. The ore is stated to have deteriorated somewhat during the last few years, and now does not average over 55 per cent. It is true that a certain proportion of ore of exceptional purity and beauty is employed in the Pennsylvania furnaces, but by far the greater part is finely divided material as above described.

The ore is deposited by the steam shovels at the mines in hopper cars which have a capacity of about 60 tons, and is conveyed by special locomotives to be shipped on to a lake steamer specially built for ore carriage. These pass through Lake Huron to Lake Erie, and unload at Cleveland or other ports on the south side of the lake. The ore is then transferred to hopper cars which travel by special freight lines to their destination. As illustrating the extent of this traffic it may be mentioned that it is claimed that more tonnage now passes Detroit than crosses the Atlantic ocean. A detailed description of the loading, shipping, and unloading apparatus would be out of place here. These have been fully described and figured in recent numbers of *Cassier's Magazine*, and will be illustrated by lantern slides. Special attention may, however, be directed to the method of unloading these large cars which is now being adopted, whereby the loaded car is run on to a balanced frame on which it is gripped, while the frame moves through the arc of a circle, as a result of which the whole car is bodily emptied, just in the same manner, and almost as quickly, as might be done with a glass of water. The apparatus is used at the Carrie Furnaces near Pittsburgh, and the author also had an opportunity of seeing it in operation at the Semet-Solvay coke ovens some four miles south of Detroit. It, too, has been described in *Cassier's Magazine*, also in the report of the *British Iron Trade Association, pp. 431—2 and 471*, and will be shown by lantern slides. Where this tipping apparatus is not employed double hopper cars are used, and one man can empty four cars, or about 200 tons of ore per day of twenty-four hours. A train of these cars conveys from 2,500 to 3,000 tons of ore in the usual course, and the cars generally convey coal back to the lake ports, as there it a considerable demand for coal in the Lake Superior region.

As the great lakes are impassible, owing to ice, for about five months

out of the year, it is important to provide stock yards at the furnaces on a scale which is altogether unknown in Europe. These stock yards run parallel with the rectangular piece of ground on which the furnace plant is erected. Overhead electric tramways are provided which run transverseley across the stock yard, and which are carried on long steel girders which traverse the yard from end to end, so that the whole yard may be readily served. During the summer months stocks are thus gradually accumulated, which are measured by hundreds of thousands of tons, and which serve as a supply during the winter months when but little outside ore is available.

Of the numerous important iron and steel works in and around Pittsburgh the author was only able, on account of time, to visit five. Three of these belong to the Carnegie Co., and are of world-wide reputation, namely, Homestead, Duquesne, and Edgar Thompson, and are all on the banks of the Monogahela River, above Pittsburgh. They are situated in the order given, if visited from Pittsburgh, Homestead, and Duquesne, being on the visitor's right hand when going up the river, and Edgar Thompson on the left The Carrie Furnaces, forming a part of the Homestead plant, have been recently erected, and are situated opposite to Homestead, but on the other side of the river. Incidentally, it may be mentioned that the Allegheny and Monogahela Rivers meet at Pittsburgh to form the Ohio river. As all the large works are near the river side, and the gradients are steep, while many deep valleys, or ravines, intersect the country, the smoke and blackness incidental to the local industries is largely confined to a limited area, and the upper parts of Pittsburgh are clean and bright, and quite removed from grime or dirt.

It may, perhaps, be of interest here to mention the plan which is adopted with visitors in these works, as it is quite contrary to our usual custom, though in at least one instance a similar method has been recently introduced in this country. The visitor, having been accredited by means of a pass, applies for admission at the gateway of the works, and, his card being found satisfactory, he is allowed to enter. The Englishmen, who is making his first visit, is then completely at a loss, for he finds himself in a works which is perhaps a mile long, and employing thousands of hands, with no one who appears to care one button where he goes, when he goes, what he sees, or what he does not see.

The visitor soon discovers, however, that he can go where he likes, ask any questions he likes, and stay just as long as he likes, and that, in fact, he has a splendid opportunity of quietly studying the whole establishment at his leisure. He may also depend upon getting full and courteous replies to all his enquiries, and the author would desire here to express his deep obligation to the many gentlemen who so

kindly did all in their power to render his visit instructive and agreeable when he arrived in Pennsylvania without notice, and without even so much as a letter of introduction in his pocket.

The blast furnace plant at Duquesne consists of four blast furnaces, together with the stoves, engines, boilers, stock yards, and other necessary plant. Of these furnaces, No. 1 was blown in in June, 1896, and the others in order, No. 4 being the last of the series, in June, 1897. Since that date, these furnaces have made some remarkable records, including what were to date the world's records, and some of which were still unequalled in June last. The highest daily output of a single furnace was made by No. 3 furnace, the product being 751 tons. The highest weekly yield was also made by No. 3 furnace in the week ending October 29th, 1898, the output amounting to 4,690 tons. The highest monthly production was 19,631 tons, which was made with No. 4 furnace in October, 1899, but this has since been exceeded by the Edgar Thompson E furnace, which made 20,188 tons in May, 1902, or an average of 651 tons per twenty-four hours. The highest year's total for a single furnace to date was made at Duquesne by No. 4 furnace, the output for 1899 being 206,229 tons, or 3,966 tons per week throughout the whole year.

These blast furnaces are 100ft. high, have a 22ft. bosh, and work with a blast pressure of about 15lbs. to the square inch. The hot blast stoves, of which there are four to each furnace, are of the Cowper-Kennedy type, being centrally fired, and provided with a separate stack for each stove. In reference to the most suitable height of furnace, Mr. Diehl, who most courteously afforded all possible information, expressed the opinion that though 100ft. furnaces work quite satisfactorily, with good coke and ore, the increasing use of ore in a state of fine division, will lead to the adoption of a somewhat shorter furnace in future, and the more usual type is likely to be from about 85 to 95 feet high. It is interesting also to note that in connection with the two new blast furnaces now in course of erection at the Edgar Thompson Works, there is being provided one stack for each set of four stoves, instead of having a separate stack to each; but each stove has two chimney pipes instead of one, so as to obtain a more equal distribution of the heat.

The furnace plant at Duquesne is associated with the introduction of the mechanical filler in 1896, and this has since been adopted, with modifications, in a number of localities in America and Germany, while there are now several such installations in this country. The original form consisted of a cylindrical receptacle with a movable hopper bottom; of this an illustration will be shown at the meeting. The later modifications are in the form of small trucks running on wheels, and of these lantern slides will be exhibited.

The steam for this furnace plant is raised by twenty-four batteries of boilers of the Babock and Wilson water-tube type, each battery being designed to generate 500 h.p., the total being 12,000 h.p., or 3,000 h.p. per furnace. As a matter of fact, these boilers are worked up to about 25 per cent. more than their designed capacity. The total cost of the whole blast furnace plant and accessories is stated to have been about four million dollars, or about £800,000. The whole of the product is taken in the fluid state to the steel works, except on Saturdays and Sundays, when it is cast in chills in a pig-casting machine.

In the summer of 1902, the Edgar-Thompson blast furnace plant consisted of nine blast furnaces, of which eight were producing Bessemer iron and one was making ferro-manganese. Two new furnaces were in course of erection, and these were being erected by the Carnegie Co., instead of by outside contractors, as is usual, It was anticipated that by this method of erection time would be saved, as the company is able to supply all the necessary materials from its own plants, and the furnaces are expected to be completed in about seven months, which is a record time for an installation of this magnitude.

The charge at these furnaces consists of about 20,000lbs. of ore, 9,900lbs. of coke, and about 5,000lbs. of limestone, or somewhat less if coke of good quality is available. The iron in the ore is practically all in the form of ferric oxide, and the content of all ferriferous material charged into the furnace, including scrap, etc., is about 57 per cent. The ore, coke, and limestone are raised and charged into the blast furnace by means of an automatic mechanical charging apparatus, which is worked by one man who is paid one dollar and sixty cents per day. A total of 33,000 h.p. is employed in connection with the furnace plant at Edgar Thompson, or nearly 3,700 h.p. per furnace.

The average coke consumption is about 1,900lbs. per ton of pig iron produced, but with good coke, and best working, a ton of pig iron is produced with about 1,750lbs. of coke. Careful records are kept of the production and coke consumption of each furnace, and these records are circulated among the managers of the various plants, so that each manager knows not only what his own furnaces are doing, but also what is being done by other similar plants. No doubt this information stimulates to friendly rivalry, and leads to healthy competition. The largest recorded monthly output of a single furnace to date was made in May, 1902, by the Edgar Thompson E furnace, the product being no less than 20,188 tons.

The following figures illustrate the monthly furnace returns, and relate to the Edgar Thompson plant in May, 1902.

Furnace.	Month's production in tons.	Coke consumed per ton of iron made.
A	4,220	2,509
B	10,330	2,135
C.	9,362	2,238
D	14,023	2,062
E	20,188	1,842
F	11,540	2,192
G	8,788	2,121
H	11,128	2,258
I	11,418	2,168

In reference to the above figures, it should be explained that A furnace was producing ferro-manganese; excluding this furnace, the average of eight furnaces running on Bessemer iron was 2,114 lbs. of coke per ton of iron made, to which must be added a loss of about 2·2 per cent. of coke due to dust, etc., in handling. If these furnaces are arranged in order, on the one hand of production, and on the other of fuel economy, they will be found to stand as follows:—

Order of Production	E	D	F	I	H	B	C	G
Order of Economy	E	D	G	B	I	F	C	H

From which it will be seen that there is a fairly general agreement with the rule that high productiveness is usually accompanied by low fuel consumption. It may be added that it is observed that as a furnace grows older and goes off its maximum output, its fuel consumption steadily increases.

It should be mentioned here that the summer of 1902 was characterised by a great demand for iron, with the result that a good deal of inferior fuel was necessarily employed. Hence the relatively high consumption of coke during the month, the average being higher than had previously been recorded at these works.

As bearing on the much discussed question of the relative length of life of furnaces having a large output, when compared with those producing a smaller yield, it may be observed that to the end of May, 1902, Furnace H had produced 1,250,000 tons of iron on one lining; that it appeared still to be in good working condition, and that there was no intention of immediate stoppage, though this furnace had already made what is understood to be a record production for a single furnace.

The cinder preferred is, of course, one which allows of quick melting, and yet gives an iron low in sulphur. Samples of iron and cinder are taken from every tapping, and are broken to examine the fracture. The cinder when thus rapidly cooled is glassy on the outside and stony in the centre. On analysis it usually yields about 35 per cent. of insoluble matter, or about 33 per cent. of pure silica. It contains about 15 per cent. of alumina, and usually not above 1·60 per cent. of sulphur

A sample of cinder which from appearance was considered quite satisfactory, was brought away by the author and analysed by Mr. G. H. Musgrove in the Metallurgical Laboratory of the University of Birmingham. Mr. Musgrove's results are as follows:—

Silica	(SiO_2)	34·58 per cent.
Lime	(Ca. O.)	45·82 "
Alumina	($Al_2 O_3$)	14·67 "
Magnesia	(Mg. O.)	1·82 "
Manganous Oxide	(Mn. O)	1·402 "
Ferrous Oxide	(Fe. O.)	1·23 "

This sample contained 1·70 per cent. of Sulphur.

The cinder is usually tapped into 10 ton slag waggons, which are taken by small locomotives and tipped, while still molten, on to neighbouring low lying land. The steep gradients in the neighbourhood of Pittsburgh allow of this being usefully done without the production of high unsightly heaps as is sometimes the case elsewhere.

The average composition of the pig iron produced at the Edgar Thompson works is approximately—

Silicon	1·20
Sulphur	·035
Phosphorus	·088
Manganese	·70

The metal is grey in fracture, fairly open in the grain, and soft to work. When tapped from the furnace it is conducted in runners made of cast-iron and lined with clay. These are a great improvement on the old method of making a channel in the sand or loam. Another improvement on the old method of stopping the tapping hole, after casting, is in general use in America. This is illustrated and described in the *British Iron Trade Commissioners' Report. p. 484*, and consists of a steam "gun," by means of which a round ball of clay is shot, or more correctly, pressed into the orifice. This arrangement saves considerable time and trouble, and also allows of more ready tapping. The blast is used at a pressure of about 14lbs. to the square inch, and all tuyeres are made of phosphor bronze, which is also freely used for the bronze water cooling boxes which are found around the lower part of all modern blast furnaces.

Where fluid metal is employed in steel making, as is very common in America, especially in Siemens practice, metal mixers are used. These are of about 200 tons capacity, and of the tilting cylinder form, such as is seen in the Wellman furnace, which type is employed not only

for steel making by the more usual method, and by the Talbot process, but also serves the purpose of a metal mixer.

It is usual to conduct the Bessemer process in acid-lined converters, the basic Bessemer process not having found favour in America. On the other hand, the Siemens process is usually carried on in furnaces which have a basic lining. The increased use of the basic Siemens process in America in recent years, has been so steady and so considerable, that it is not unusual to hear predictions that soon the Bessemer process will be a thing of the past!

At Duquesne, there are in the Bessemer steel department two converters which are supplied with fluid metal from a 200 ton tilting metal mixer. (See *British Iron Trade Association Report, p. 515.*) Each charge averages about 9½ tons, and the total production per 24 hours is about 2,100 to 2,200 tons of ingots, which are usually 20½in. by 18½in. at the larger end, and will weigh about 5,300lbs. each. Usually these two converters turn out about 110 heats of 9½ tons in 12 hours, but the shop record is 131 such heats in 12 hours; while in October, 1901, no less than 55,500 tons of ingots were made in 27 working days.

In the Edgar Thompson Bessemer department there are four converters, but only three of these are in use at one time, the other being in repair or reserve. Here each heat weighs about 14½ tons, and the average output is about nine heats per hour, or something over 3,000 tons in 24 hours, the ingots weighing slightly less than two tons each. The spiegeleisen used as an addition at the end of the blow is previously melted and added in the fluid state.

At Homestead there are two converters which are supplied with metal which is melted in cupolas, sufficient steel scrap being also melted in the cupolas to give a product with about 1·2 per cent. of silicon. The original pig iron is grey and open in the grain, being richer in silicon than is employed for steel making in America. The lower portions of these cupolas are lined with a mica stone, while above the melting zone the lining is of sandstone. Though quite large pieces of steel scrap are melted in these cupolas, the linings are found to resist the high temperature satisfactorily and to wear well. The cupolas run continuously from week end to week end, being repaired on Saturday nights and Sunday mornings. The only special precaution taken appears to be to charge the big pieces of steel scrap into the centre of the cupola, as this saves the wear on the linings. Each cupola melts about 415 tons of pig iron in 24 hours, and the output averages quite 1,200 tons of small blooms, from the mill, every 24 hours. Although a low silicon iron is purposely employed in order to allow of rapid working with small loss, the charge in the Bessemer vessel sometimes works too hot, and to remedy this, arrangements are made whereby steam is blown through the charge in addition to air. This cools the metal, the

temperature of which can be readily controlled, while an increased volume of gas is produced, which burns at the mouth of the converter with a characteristic green flame, due presumably to the presence of volatile carbon compounds.

In the Siemens basic process. as conducted at Homestead, hot metal is employed, and this is brought in ladles by locomotives across a special bridge over the Monogahela River from the Carrie furnaces, which are, as already mentioned, opposite Homestead but on the other side of the stream. The iron is first mixed in a tilting, gas-fired, basic-lined, mixer, and the composition of the metal as used is about:—

Silicon	·50	—	·80.
Sulphur	·04	—	·08.
Phosphurus	·16 per cent.		

In the basic Siemens melting shop, at Homestead, there were 16 furnaces, arranged in two parallel rows. The author was informed that the method of working varied somewhat according to the amount of scrap, etc., available, but that the following may be regarded as being fairly typical The total charge weighs about 90,000 to 100,000lbs., of which roughly one-half is scrap. The ore used for bringing about the necessary re-actions in the furnace is a dense red hematite of exceptional purity. The fuel is natural gas which is used more on account of saving of labour than of economy of price. The average time taken to work off a heat of from 40 to 50 tons is 7½ hours. At the end of the process the decarburized metal is run into ladles at the back of the furnace, and here the necessary recarburization is effected by the addition of anthracite which is put into the ladle before the metal is run in. The anthracite is in pieces about the size of a nut, and is contained in paper bags each of which contains some 50lbs. of coal. The number of such bags added naturally varies with the carburization desired.

The rapidity with which such large charges can be dealt with in America appears to be due to two chief causes—

(1) The use of cast metal low in silicon and which also contains much less phosphorus than is usual with basic working in Europe.

(2) The adoption of the Wellman charging machine. This was fully described and illustrated in the paper read before this Institute by Mr. Head, so need not be here described. The author was informed that machines of this type are now in almost universal use in the United States, and that they effect a saving of about 25 per cent. in the time required to work off a charge, with a consequent reduction of fuel, labour, and dead charges.

The Talbot process was installed in Pittsburgh last summer at Messrs. Jones and Laughlins'; but as it had only been in operation a fortnight at the time of the author's visit, and had not settled down into regular working, it was suggested that it was rather early for strangers to see so

ung an infant. Upon that subject, therefore, no additional infor-ation can be here supplied.

The old system of pouring and stripping ingots in a casting pit close the converter, or the open hearth furnace, was productive of much loss time, inconvenience, and sometimes, too, of accidents. This method dealing with the molten steel has now been largely superseded by the e of ingot moulds mounted on separate trolleys which run on a small lway. Usually eight such moulds are placed together in a row, the arge being sufficient to properly fill seven moulds, and the other being reserve. In order to ensure soundness, a small piece of aluminium placed in the bottom of the mould before the metal is teemed. When e moulds are filled they are drawn out of the steel melting house into e open, where they are stripped by a hydraulic ingot stripper. The elting house is thus kept clear and cool, and production much pedited. The ingots are of two shapes, one being rectangular for dinary purposes, and the others slab like for rolling into plates. The lgar Thompson Bessemer ingots weigh rather less than two tons ch.

It is apparently the usual practice for soaking pits to be used with essemer ingots, while Siemens' steel is reheated in regenerative rnaces. The soaking pits are of the ordinary vertical type, the top of e pit being on the usual floor level. The pits are charged and emptied means of overhead electric cranes. Each hole holds four ingots, and Homestead the pits have been recently enlarged to 5ft. 3in., inside easure, so as to take four ingots each 20in. by 18in. in size. At the lgar Thompson works there are 16 soaking pits for Bessemer ingots, d each pits holds eight ingots, or one charge from the converter, and ien fully employed the soaking pits have 16 separate heats in process one time. These soaking pits are heated by means of natural gas.

Siemens steel ingots are usually heated in furnaces which are also ed with natural gas; sand beds are employed, while the ingots are arged and withdrawn by means of an electric charging apparatus so anged as to serve a number of furnaces, and to be operated by one n.

The further treatment of steel forms a connecting link between the rk of the metallurgist and that of the engineer, and belongs more perly, perhaps, to Mechanical Technology, which is a recognised ject in other countries, though unknown at present in the United ngdom. This paper would, however, be incomplete without some erence to the remarkable production common in American mills.

At Homestead there is a modern plate mill which deals with basic mens steel ingots of about 2½ tons in weight. The ingots are first eated in regenerative furnaces, fired with natural gas, being charged l withdrawn by an electric charger. They then pass to a universal

mill of about 8,000 h.p., which is steam driven, but the ingots are raised and lowered, and the vertical rolls adjusted, by means of hydraulic machinery, which also raises and lowers the doors of the reheating furnaces. The plates are rolled to 110 feet in length, are 30in. wide, and of an average thicknes of about ¾ of an inch. They are finally straightened, while still hot, in 110ft. lengths, by steam pressure applied laterally. The average production is about 500 tons in 24 hours.

The Edgar Thompson Bessemer rail mill is celebrated for its remarkable output. There the ingots, after being removed from the soaking pits by an electric crane, are carried by an electrically driven endless rope to a universal mill The ingot here makes two passes, being raised, lowered, or moved by a table worked by hydraulic power. The mill is a continuously running one, there being no reversal, and the smoothness and rapidity of working is very striking. The bloom so produced is now mechanically conveyed to the hot shears for the purpose of being cut into two pieces. The larger one of these pieces is of definite length and is intended to be rolled into two rails, each 33ft. in length, and weighing about 80lbs. to the yard. The smaller piece, or crop end, is rolled in a separate smaller mill for the production of lighter rails.

The large pieces, which are rolled in No. 1 mill, on leaving the hot shears, travel on live rollers to the re-heating furnace, into which they are charged with an electrically driven pusher, and when ready, are withdrawn by a similar mechanical apparatus through opposite doors on the other side of the furnace. Each furnace is provided with nine doors on each side, so as to take the blooms from a heat, and there are, in all, five such furnaces. From the re-heating furnaces, the bloom passes to the rolls, which are arranged in sequence, in a line, so that the material passes straight forward from the heating furnace to the railway car. The first set, or roughing rolls, are three high, and here the steel makes five passes, after which it is taken by live rollers to the second, or intermediate rolls, which are also three high, where it again makes five passes. The rail is now taken to a cooling table, where it is allowed to remain and cool in the air somewhat, this special treatment being known as the Morrison-Kennedy system, the object being to develop the most suitable internal molecular structure. Incidentally, too, it is stated that this process leads to the formation of a scale of a peculiar thickness and character which readily peels off when the rail is again rolled, so that the finished rail has a much smoother and cleaner surface than usual. After the rail has thus been permitted to cool in the air for about a minute and a half, and the proper temperature has been attained, it passes to the finishing rolls, which are two high, and through which it only passes once, and so to the yard. The average production of this single mill is about 1,000 tons in twelve hours; but this output, large as it appears in contrast to British practice, has been frequently exceeded in this mill.

Returning now to the smaller pieces, or crop ends, these are taken on a small electrically driven trolley to the smaller or No. 2 mill, to be rolled into lighter rails, weighing about 30lbs to the yard. The pieces are first re-heated in a natural gas-fired regenerative furnace, into which they are charged by the aid of an electrically driven ingot pusher. This smaller furnace is arranged so that one slab enters at each door, and the whole of the charging and withdrawing is accomplished by one apparatus which is worked by a single youth. The metal, when hot, is passed in succession through three sets of rolls, each three high, and it is never once touched by hand throughout its journey, as it is handed from one set of rolls to another by a fork-like appliance which works with a regularity, and, one is almost tempted to say, intelligence, which is apt to strike the observer as being almost uncanny. The rails are ultimately hot sheared into three lengths, each 30 feet long, and weighing about 30lbs, to the yard. This smaller mill produces about 300 tons of light rails in 12 hours, the total production of the two mills being from 1,300 to 1,500 tons per shift, and each mill works 12 shifts, each of 12 hours, per week.

Lengthy lists of suggestions and conclusions have been drawn up by individuals or deputations who have visited America and recorded the results of their observations and enquiries, and no doubt many of the reasons which have been thus advanced in explanation of the remarkable industrial progress of recent years are worthy of careful consideration, for the causes which lead to great national expansion are doubtless often complex and difficult to accurately estimate; but in looking back on the impressions of this brief visit three things appear to be worthy of special remark.

Of these, first and most interesting is the people. It is true that in the manufacturing centres of America there are to be found a large proportion of negroes and also Italians and Hungarians—not to mention those of Teutonic or British extraction—but speaking generally the leading positions are occupied by men who are American born, and those of other races, in the first place at all events, are merely day labourers. They are apparently regarded as of little account, since if one falls out newer immigrants are always ready to take his place. Those who are really responsible for the conduct of these vast enterprises are usually thin, lithe, active, keen, clean-shaven, young looking men; who work twelve hours a day, six days a week; who take little alcohol, but often consume a good deal of tobacco; who always have an eye to the main end in view; who lead what is now so much talked of as the "strenuous life;" and yet who have always a frank and courteous reception for a stranger. But perhaps nothing about them is more striking than their buoyant self-confidence, which is based upon their acknowledged success in the past, and which is, after all, the best guarantee of success in the future.

Secondly, distance exerts a most important influence. If the United States be compared, area for area, with other parts of the world, it is doubtful whether the provisions of nature were any more bountiful on the one side of the Atlantic than the other. The difference appears to be rather that in America we have to deal with a comparatively new country, where the natural resources are being exploited as rapidly in one year as in ten years in an older land. The difficulty of transport having been once overcome, the mineral resources of immense areas were rendered available, so that furnaces were no longer restricted for their raw materials to the products of a particular district, or confined in their markets to a local area. It thus became possible to plan works on a scale limited merely by the capital available, and to adopt mechanical contrivances and economies which would be impossible with less gigantic undertakings. Distance has thus almost ceased to be a disadvantage, but acts benefically in increasing the total volume of trade, and in diminishing the natural fluctuations of the market.

Finally, the educational system of Canada and the United States calls for remark. The subject is too important to be dealt with in a paper of this kind. It may here be merely observed that faith in the utility and necessity of education is firmly fixed in the American peoples. Wealthy citizens are prepared to subscribe with more than princely liberality to the cause; parents are willing to make heavy sacrifices so that their children may be taught; while the students themselves are in many cases so enthusiastic that they are prepared to live during the session on the money they are able to earn during the vacation rather than enter upon their life's work ill prepared. Hence our system of evening class work finds little favour in America, the students passing through the primary and secondary schools to the College or University, where four years is spent in strenuous work. The result is that the students in applied science at the higher centres of learning are numbered by the hundreds at each University, while the course of work is so systematic and thorough that manufacturers recognise that the men thus trained are the best they can obtain in order to direct the most important industrial undertakings, and students who have graduated experience no difficulty in obtaining suitable employment. Until a similar condition of affairs exists in this country it cannot be suggested that the need for higher technical training has been satisfactorily met.

LIST OF LANTERN SLIDES

TO ILLUSTRATE PROFESSOR TURNER'S PAPER.

Nos. 1, 2, 3, Iron Ore Mining, Lake Superior.
,, 4, 5, Shipping and Transportation of Ore.
,, 6, 7, Emptying Cars of Ore.
,, 8, 9, Handling Ore at Stockyards.
,, 10—15, Blast Furnace Charging—Old Style and New.
,, 16, Stopper for Tapping Hole.
,, 17, 18, Metal Mixers.
,, 19, Wellman Furnace.
,, 20, 21, Casting Ingots.
,, 22, 23, Stripping Ingots.
,, 24, 25, Ingot Charging.
,, 26, 27, Heating and Forging large Ingots.
,, 28, 29, Automatic Charging Apparatus, at Sheepbridge, England.

THE DISCUSSION.

Mr. PILKINGTON: It seems to me a very happy idea for workmen and works' managers to go over to America. It is better still for our professors to be sent over there. Such visits are a liberal education in themselves. People hardly credit what progress is being made across the Atlantic. Even your own personal friends, when you come back, accuse you of spinning yarns. It is not very long since I was there, but I feel it is time I went again, for things move so fast there I have been struck also by the fact that some of the charging arrangements which are being introduced in this country, and termed American, are in America already old-fashioned. Middlesborough is about to erect one or two charging machines—at Bolckow Vaughan's and at Cargo Fleet—two are at work on the West Coast and one at Sheepbridge, whilst Palmer's are erecting another. Notwithstanding all their protests, English ironmasters are gradually realising that they must do it. I cannot altogether agree with the author's suggestion that ores of such qualities as they have in America are obtainable in this country also. They may be, but I am afraid they are in such microscopic quantities that they are hardly worth considering. When I was there, I formed the opinion that American ores were of splendid quality. Mesabi ore is very fine, and therefore. presents difficulties in the way of smelting; but the Americans are not deterred. They say that if they cannot get blast through by ordinary means they must get sufficient power to "push" it through. It seems as though these great furnaces are driven by sheer force. One notable feature of the American iron trade is the enormous quantity of material which has to be dealt with. The (to an Englishman) appalling quantities of ironstone and other materials available enable Americans to spend vast sums of money in transport and in general handling arrangements such as are impossible in this country. It is possible to spend capital and make a magnificent works and yet not be able to make a profit or pay interest on the outlay. As an illustration of this take Germany. German works are splendidly equipped, but a great many forget to pay dividends. Another advantage which the Americans have in ironmaking is their magnificent coke, Every furnace manager will agree with me that, for several years past, owing to the so-called "improvements" in coke making (which seem to consist in an admixture of ingredients which they never could mix before), English coke has been deteriorating. But in America they seem to be able to get abundant supplies of pure coke. Compared with America, we are, in this country, face to face with the problem of having to use up the odds and ends of material left by our ancestors. Then again, the transport arrangements in America are wonderful. One of the salient factors in their blast-furnace success is, I think, the way in which their engineers have grasped the methods of handling ores by the principle

of gravity. Their idea is to use such appliances that the ore gravitates from wagons and bunkers pretty much of its own accord. "Mechanical technology" does not seem a pretty term, but it adequately describes the want of England. We have not taught our engineers how to handle materials. We do not seem to have any professional men of that type in this country, except, perhaps, in gas works. The Americans have such a class of men, brought up and trained in the handling and transport of materials, about their iron and steel works. It is curious that whilst they make such a success of the matter in their own country, many American engineers have burnt their fingers in handling our materials. Referring again to the fineness of the Mesabi ore, I have seen men in America with long irons ramming at the ores in the bunkers to make them move. Their system would not suit some of the English ore, because some ores in certain weather are like mud and stick together in a heap. I saw their method of wholesale mechanical casting on bogies, stripping, soaking, and handling the ingots and blooms right away through tandem mills at a tremendous rate. This system is also a magnificent illustration of their engineering abilities, and also of the vast capital invested in such work, which has a basis only in the immense quantities of materials available. Professor Turner made a point about American managers being young. Yes, they are all young. I am afraid they don't live very long. What struck me most when there was the apparently rapid production of Carnegie's, Morgan's, Schwab's, and men of that sort. At any rate, managers are in their positions a very short time, and, I suppose they are either killed off by overwork or else become employers. Any way, every time any friend of mine has been over there I have asked him about such and such a man, and the reply has always been, "Oh, there is someone else managing now." The fact is they change their managers with extraordinary rapidity, and the time is quite long enough for them, if they want to live. You never see an elderly manager in America. They die young. Then again, the Directors, or members of Boards of Control, are of a very different type to what they are here. They are the enterprising men there. Are they the enterprising men here? I leave that for you to answer. They are men who live as "strenuous" a life as their managers and workmen. In conclusion, I am very much indebted to Professor Turner for what is to me like a very pleasant *resumé* of a very pleasant journey of my own.

Mr. Walter Macfarlane: I would like, at the outset, to add my thanks to Professor Turner for what we are all agreed is a very excellent paper. It is a difficult matter to take up a subject like this and give fresh and interesting information. We must admire the masterly manner in which the Professor has marshalled his figures and made them entertaining and interesting. The first point that strikes me is as to whether it is possible in this country to obtain ores as pure as in America. I think the quantity must be microscopic. Does the Professor think that such pure ores are to be mined in this country in anything

like sufficient quantity, or are they (after importation) to be purchased in this country? If so, I venture to say it is at such a price that no blast furnace manager can work them at a profit. We, in this country, are not so much concerned about big outputs as they are in America and the Continent. We are concerned in getting dividends out of such materials as we can command, and a difference of 1 or 2 per cent. in the quality of the ore will make a great difference in the year's profit. A hematite ore of absolute purity could not contain more than 70 per cent. of iron. But we are tied down to ores averaging less than 50 per cent. Can we get Cumberland ores which are, on the whole, richer than that? Imported ores have been going down in purity year by year until we may say they are under 50 per cent., a fact which Mr. Whitwell in his presidential address to the Iron and Steel Institute, called attention to last year.

A good workable ore would contain 65 per cent. of iron. Well, there is a margin of 15 per cent., that is to say, 50 per cent. compared with 65 per cent. And that 15 per cent. deficiency in iron means 15 per cent. impurity to be fluxed away. That calls for additional lime and also means more fuel. The bulk of *excess* slag will be twice the bulk of the pig iron produced. On running these materials through the furnace, the iron is smothered in twice its own volume of sometimes semi-sticky material. Under those circumstances I am inclined to think it is a little bit cruel on the Professor's part to say we have such pure ores, because this paper, coming as it does on the authority of Professor Turner, will get into the hands of some directors, and they may consider that managers ought, therefore, to do wonders.

We have been delighted to see the pictures of what America is doing in the way of handling material. But we must not shut our eyes to the fact that English people are doing something. Last year there were thrown on the screen pictures of charging apparatus in North Lancashire, in Cleveland, and also at the Park Gate Works in Yorkshire. The fact is, that we are not so far behind as some people believe. We are a slow-going people, but in the end we do come in. It is a pity to make believe we are always asleep. Sir James Kitson said lately that it was poor policy to be crying ourselves down and crying our rivals up, and he said "If we are to go on at this rate we shall be taken at our own estimate in the markets of the world."

In the paper there is also a beautiful paragraph about the men. In connection with that this question arises, If a young man in America will cut himself off for four years from chances of earning money, and become a graduate, is it worth while doing that in order afterwards to lead the "strenuous life" for twelve hours per day and be very soon killed off? Then as to modern universities and their splendid arrangements and large areas, I am sure we all wish our own Birmingham

University every success. Our best wishes go with the Professor with regard to this University. But I leave it with you, gentlemen, to consider whether a large University is quite the right place to take up a technical branch of applied science. I have in my mind a technical college which was established because of variance with a University the heads of which concerned themselves with such petty details as that the students must wear a certain colour and cut of gown. The college I refer to was set up a century ago by a far-seeing professor. He was the first one to apply for a college charter devoid of religious tests and open to both sexes. He saw even then the advantage of an intimate intercourse between the college and the works, and so set up a class of his own for the instruction of workmen. That was the beginning of technical instruction in our country, and the young men trained there do not attain to the dignity of graduates, but they have no difficulty in securing good appointments, because several firms send to that college when they want a works' official. The idea of young men working out, educationally, their own salvation, has been going on in Scotland for 200 years past. Then Professor Turner says, "Our system of evening class work finds little favour in America." Well, I think they stay longer at school there than we do. But still it would be a pity if our evening classes did not go on. There is such a thing at the present day as "rampant hooliganism." Education tells against that sort of thing, and therefore I am extremely sorry that there is a tendency at the present time amongst educational authorities to seek to strangle evening classes. We cannot now get one fourth of the money from the Government for evening schools that we could last year for certain high class work.

In conclusion, I may say I have been delighted to come and listen to the Professor to-night. He is a gentleman of world-wide reputation and great attainments, and if we can only get the authorities to back him up in Birmingham, I am sure he will do an immense amount of good in the district.

Mr. Isaac E. Lester: I note with much pleasure what it is intended to do at the Birmingham University in connection with the economics and metallurgy of iron and steel manufacture.

I have been much interested in the points raised by the last speaker, having also been—a little time back—practically engaged with the problems of technical education at evening classes as applied to the metallurgy of iron and steel manufacture, and while in full sympathy with such, as far as they go, am of opinion that better results will be obtained by an extended course at a University.

After a few years absence abroad it is particularly noticeable where and what improvements are to be found in the old country. The works on the North-east and West Coasts are now reaping the benefits of

increased output and economic working, consequent on their managers and engineers having modernised their plant. I have seen the method of ingot casting, stripping, etc., also the one man blast furnace charging apparatus—as show on screen—working very satisfactorily in this country. It is regrettable, however, to find that the Black Country does not show any marked improvement.

It pays for those holding responsible positions in works to travel and see what their competitors are doing, and students, at some stage of their University course, would likewise find it of great benefit in rendering them more capable for their after association with the industy.

Referring to the use of fine ores in American blast furnaces. If the finely powdered one is dumped in without admixture with other ores less fine, it is a risky practice, because there must be a certain amount of passage for ascending gases, which such fine ore is likely to prevent and thereby cause all sorts of obstructions. Perhaps Professor Turner will explain if this is the ordinary every day practice. I have successfully used a similar, but richer, one in the open hearth furnace, by moulding it into bricks by hand and using cheap native labour, such as is obtainable in the East, and thereby preventing any chequer obstruction or other trouble.

Mr. J. W. Hall: I have heard of a great many of the plants to which Professor Turner refers, and the thing which always strikes me most (after the fact of their exceedingly cheap fuels and high grade ores) is what I may term the "American's engineering common-sense"—a common-sense so great that it may almost be said to amount to genius. If they want (for example) to dig ore, and find the load too heavy, they put a steam engine behind the shovel, which they bring on a crane. If they wish to fill a blast furnace they don't send a man with a barrow to the top, but make the wheelbarrow run up by itself and tip its load into the furnace automatically. To charge open-hearth furnaces they bring up their materials in large spoonfuls, so to speak, and the loose handle takes hold of the bowl of the spoon, and tips the charge into the furnace. Then again, for heating furnace charging they use a large pair of tongs with a steam engine or other power behind to move them. Much of their success is due to their ingenious methods of handling material. We in this country are rather backward as to our methods, but we have not to deal with anything like the same quantities. Mechanical improvements only pay where large quantities have to be handled. Even the Yankees themselves have in some cases gone too far in the direction of mechanical handling. I saw in the *Iron Age* that when the combination of all the American steel works was formed, and they came to compare notes, it was found that some of the smaller works, built 20 years ago, were actually a better investment than the more modern ones. One of the chief features about these combinations which impresses me is the change which will take place with regard to

little things. The Americans, apart from their genius in handling large matters, are also very careful about small details. At the present time the members of these great combinations are exchanging information about every little detail, and the revelations which have been made in that way are most startling. The little differences in practice between the various works, which would appear to be of small moment by themselves, are being compared, and a very great improvement in the returns of the combination, as a whole, is likely to result.

Mr. H. E. PARTRIDGE compared English and American methods of rolling steel plates and rails, and expressed the opinion that the English method was the more economical one. He agreed with Professor Turner that what was needed in English works was improved plant, increased output, and decreased waste. In other words, greater efficiency with more economy.

Mr. Jos. COLLEY: It struck me whilst Professor Turner was reading, that we are not so backward even in old Bilston. Last evening we got about 395 tons out of one of our cupolas. There certainly are some good works in England, and our own country in also trying to further improve. If we had the plant we could make anything from a thousand tons up. It all depends upon the plant. The men are here.

PROFESSOR TURNER, replying to the discussion, said: I am much obliged for the way in which the paper has been received, and for your kind remarks about myself. In reference to the remarks of Mr. Macfarlane. One who for eight years has occupied the position of Director of Technical Instruction in Staffordshire, is not likely to change his views just because he has gone to Birmingham. I believe there is a very wide opening for evening classes, and that there are large requirements for them. At the same time, I suggest that those evening classes are more for our workmen, and not for the managers and sons of proprietors who can afford to give money and time to obtain a higher training. As to the purity of ores, I said the difference was not in quality but in quantity, and that is what my critics have said. But I may say that I was travelling in the train a short time ago with one of the directors of a large mine in the North of England where they get a very good dividend and have wonderfully pure ore. I do not believe they issue any report or that their shares are for sale, but I know that they do have magnificent native English ore. And if you cannot use it in your blast furnaces it is, as I say, a question of price and not of quantity. Then I am criticised for saying we are behind. Well, when I was abroad I did my level best to say what I could for the old country, but when I came home I enquired in the North of England, Scotland, and Wales to find if there were any of these charging appliances, but could not discover any. Then I came to Staffordshire, which used to lead the world 40 years ago, but I could not find those appliances here either. Referring to mechanical fillers, the words occur in my paper, " there

are now several such installations in this country," and several have been quoted—but not more than several. And I suggest that when these large districts are not using them it is folly to suppose that we are keeping abreast with our neighbours across the water. Mr. Macfarlane asked what was the good of young men studying for four years and then only to have a few years of "strenuous life." But the answer is that if a young man is in America he has to live "the strenuous life" whether he likes it or not, and he can please himself whether he leads it as a workman or as a manager, and which it is to be depends largely upon the way he prepares himself. As to technical instruction in colleges, Mr. Macfarlane seemed to say at first that it was not the right thing, and then he said it had been successfully tried for a long time in Scotland. But I would suggest that a University is the right place for higher technical education. Is it not so in America, and France, and Germany. Are we to devote all our time to classics and not take the bread and butter subjects which benefit so much the trade of the country? The success of the movement which is now in progress in Birmingham will depend upon whether or not we can get sufficient support. It is ultimately a question of money. What has to be considered is not that students cost so much per head. For if, say, a cookery student costs 5s. 6d. per head you cannot expect an evening metallurgical student to cost less than £5 10s. per head. Higher training will need different apparatus, and more money in every way. If the neighbourhood once recognises that we have a sufficient number of good students who, as they leave, are obtaing good situations, then I feel sure the Midlands will support the University when it is doing a really useful work.

Mr. WALTER MACFARLANE: I should like to explain, with reference to Professor Turner's remarks about Universities, that in Glasgow there was a University which developed graduates, and one which did not. I went to the one which did not, and I do not regret it.

THE PRESIDENT: I propose a hearty vote of thanks to Professor Turner for his paper. I feel we are very much indebted to him. He has confirmed my conviction of the necessity for a waterway from the Midlands to the Coast, if we are to meet the growing competition of other countries. I believe the metallurgical department of the Birmingham University is going to do great things, because our good friend Professor Turner so well understands the requirements of this district. Mr. Pilkington says the heads of the concerns in America work with their managers. I wish it was so in this country. I wish we could see more owners and the directors of works at our meetings. If South Staffordshire is going down, it is the fault of the proprietors themselves. Their managers do their level best to keep up-to-date, but they are not encouraged by the employers. Engineers can readily

vide the machinery if the owners will order it. I am sure we all nk Professor Turner most heartily for his splendid paper.

Mr. L. D. THOMAS: Nothing gives me greater pleasure than to second resolution you have proposed. It is not this evening only, that we e derived benefit from Professor Turner. We have heard much out the courtesy of Americans, but I am sure that there is no man in ierica who can be more courteous than he is. There are many oortant points in this paper, and they require a great deal of thinking r.

The vote of thanks was put and carried by acclamation, and suitably nowledged.

The Third Meeting of the Session was held at The Institute, Dudley, on Saturday, 13th December, 1902.

The chair was taken by THE PRESIDENT (Mr. WALTER SOMERS).

The minutes of the previous meeting were read, adopted, and signed.

THE PRESIDENT: Some of you will have heard with great regret of the death of Mr. David Crofts, an old member of our Institute. I am sure those who knew him will regret it very much. We feel his loss, and I therefore move a vote of sympathy with his friends in their bereavement.

Mr. PIPER seconded the resolution, and the Secretary was asked to forward it.

Mr. J. S. JEANS then read the following paper:—

LESSONS FOR THE BRITISH IRON TRADE FROM AMERICAN EXPERIENCE.

By J. STEPHEN JEANS (Secretary of the British Iron Trade Association).

The overshadowing influence of the recent development of the iron industry of the United States on the course and outlook of the iron trade of our own and other countries has naturally drawn the attention of British manufacturers to the question of how far this country is likely in the future to be able to hold her own in competition with our greatly-favoured and indomitably active and enterprising Trans-Atlantic rivals. This subject has been so often before your own and kindred societies that I should almost have thought you had had the facts before you *ad nauseam*. As, however, yeu have done me the honour to call upon me to make one further contribution to the mass of literature already available on the subject, I have pleasure in complying with your wishes, while greatly fearing that it is difficult for either myself or any other writer to add much to the subject that can be regarded as new.

The essential differences between British and American iron making conditions are many and important. Briefly, however, they oonsist of the following:—

British.	*American.*
ORES :—	
Large quantities of lean.	Small supplies of lean.
Small quantity of rich.	Large supplies of rich.
Mostly mined by shafts.	Largely mined by quarrying.
Ore field close to coal	Ore field remote from coal.
Coal carried to ores.	Ore carried to coal
Transport mainly by rail.	Transport mainly by water.
FUEL :—	
Mostly within 30 miles of furnaces.	Close to furnaces in South ; 50 to 500 miles in Middle and Eastern States.
Coke getting dearer and more scarce.	Coke still cheap in South ; getting dearer elsewhere.
Supplies still adequate, but scarcity likely in 50 years.	No sign of scarcity.

British.	*American.*
BLAST FURNACES:—	
Mostly within 20 miles of sea.	Mostly in W. Pennsylvania, 400 to 500 miles from sea.
Furnaces generally of small dimensions.	Furnaces generally of large dimensions.
Average out-put per year per furnace, about 25,000 tons.	Average annual out-put per furnace, 60,000 tons.
Usual pressure of blast, 4 to 6lbs.	Blast pressure, 10 to 20lbs.
Average ore consumption per ton of pig, about 2½ tons.	Average ore consumption per ton of pig, 1¾ tons.
Average labour cost of pig at furnaces, about 3s. 6d.	Average labour cost, 2s. to 2s.6d.
Small volume of blast.	Large volume of blast.
Furnaces have long life.	Furnaces have short life.
Average percentage of iron in home ore, about 38 per cent.	Average percentage of iron in home ore, 50 per cent.

IRON ORES.

So far as raw materials are concerned, the United States have of late years been able to bring down their costs enormously. This is largely a function of the discovery and development of new ore fields in the Lake Superior region. When I went over that region in 1890, the only ranges opened up were those of Marquette, Vermilion, and Menominee. Since then the Gogebic and the Mesabi ranges have been added to the number, and these two ranges now collectively produce a much larger quantity of iron ore than that, either then, or since, produced collectively by the older ranges. Not only so, but the ore is almost of the same percentage of iron, while being much more cheaply worked. Simultaneously with this development, there has been a large expansion of the cheaply worked ores of the Southern States, while there has been a concurrent relative decrease of the output of the more costly ores of New Jersey, New York, Pennsylvania, and other eastern and middle States. The influence of this movement on the cheapening of the raw materials used in American blast furnaces has been very notable. The census industrial records show that while the average cost per ton of the ores used in the United States as a whole was 4·31 dols. in 1890, the average fell to only 2·53 dols. per ton in 1900, showing a decrease of 1·86 dols., or about 7s. 6d. per ton of ore, which would correspond to about 12s. per ton of pig iron. There has been a concurrent decline of 68 cents., or 2s. 10d. per ton, in the average cost of coke, and of 14 cents., or 7d. per ton, in the cost of flux, over the same period, while the average cost of mill cinder and scrap used has fallen by the sum of 34 cents, or 1s. 5d. per ton. To the extent of these reductions in the cost of the raw materials used, it can hardly be claimed that credit is due to the American iron industry, as such.

The change is mainly owing to the discovery of new sources of supply, and their successful application to the wants of the country by those who exploited them.

The iron ore supplies of the United States were cheapened and improved by the development about ten years ago of the Mesabi range, which, from a trackless waste in 1891, was opened up by railway in 1892, produced nearly three million tons of ore in 1895, had raised well on to five million tons in 1898, and in 1901 had turned out the colossal figure of over nine million tons, making it the most productive iron ore field in the world.

The proportions of the total iron ore output of the United States contributed by the Lake Superior region at different dates were as follows—in thousands of tons:—

Year.	Total output, U.S.	Total output Lake Superior ranges.	Percentage of total supplied by Lake Superior.
1880	7,120	1,987	27·91
1885	7,600	2-466	32·45
1890	16,036	7,071	44·09
1895	15,957	10,429	65·36
1900	28,887	20,589	71·49

As one example out of many that illustrate how economies have been ntroduced into American practice, the abolition of the old system of trimming cargoes may be referred to. Up to a few years ago many men were employed at high wages to trim the cargoes of ore leaving Lake Superior ports. But of recent years this expense has been done away with, because the much larger size of the vessels employed rendered them stable in all weather, and any inequality in the trim of the vessel is adjusted by the shifting of water ballast. This gets rid of an extra handling, and every extra handling is, of course, an addition to ultimate cost.

WAGES.

A good deal has been made at different times of the higher wages paid in the iron industry of the United States. One gentleman who visited that country last year came back with the story that he had been informed by Mr. Schwab that he paid his workmen twice the wages paid in England, and got three times the work out of them. This is an important statement, if true—I mean if it applies to the trade generally. But we may bring the matter to a much better test than that afforded by the wages paid by an individual employer or group of employers. The census returns show that the average annual wages paid to all classes of workmen employed in the iron and steel works of the United States, was £89 in 1890 and £96 in 1900, and for the latter year the average varied from a maximum of £145 in Illinois to a

minimum of £49 in Tennessee. Now, although we have, unfortunately as I think, no census of the average wages in this country, for either the iron or any other industry, yet I have the means of knowing that the average wages paid at some of the largest industrial establishments in this country, embracing blast furnaces and steel works, varied some years ago from £65 to £79 per annum, and took a higher range in 1900. This gives a difference of much less than that named. In the United States, as in our own country, there are great, and, as I think, unjustifiable differences in the rates paid to ironworkers. In one establishment, devoted to an industry familiar to South Staffordshire—that of sheet rolling—I found unskilled Poles and Hungarians being paid a dollar a day, while the head rollers were being paid as much as fourteen dollars. There, as here, the great difficulty is that good rollers are difficult to procure. They are, more or less, a close corporation. The head rollers in some British works are almost, if not quite, as highly paid as the chief rollers in the United States. I have asked employers here why they were content to go on paying such high wages. The reply I have met with has been that the rollers were a special body of men, strongly organised, and that if they were to go on strike, it would probably be difficult to replace them—the more so that they take good care to limit their possible numbers. This is less the case in America, otherwise, of course, the enormous development that has taken place in the sheet, wire, and other branches of the American steel industry would have been impossible. Indeed, I heard Mr. Schwab state that he could take a fairly intelligent agricultural labourer, fresh from the plough, and make a roller of him in a few months. If this can be done there, it can surely be done here as well, and if it can be done here, the extraordinarily high wages paid to these men surely calls for further explanation.

The tendency of wages in the United States has been to increase for many years past, but in some States the increase has been much greater than in others. A comparison of the census returns of the total wages paid to the total hands employed in each of the census years—1890 and 1900—shows that the average annual wages paid in those years in the principal States engaged in the iron industry, were :—

	Average wages paid in Steel Works.	
	1890. Dollars.	1900. Dollars.
Pennsylvania	552	562
Ohio	585	594
Illinois	595	547
Alabama	462	486
W. Virginia	434	519

In appendices A, B, and C, I have given comparative returns of average wages for the years 1890 and 1900, collated from the census reports. It will be noted that the average paid at blast furnaces is

materially under that paid in steel works, the difference for Pennsylvania, the controlling State, being about £25 per man per annum higher in steel works.

PROFITS.

The impression appears to have got abroad that the iron trade is an El Dorado, and that those engaged in it have at last mastered the secret, so anxiously sought for by the ancients, of transmuting all baser metals into gold—at any rate, in the United States. Those who are engaged in the iron trade of this country know from long and anxious experience that such a transmutation is as difficult in modern as it was in ancient times. The world has looked on with amazement and envy while the U.S. Steel Corporation has, since its foundation more than twenty months ago, been piling up hundreds of millions of dollars in the form of profits. The fact is overlooked that this has only been done during a period of abnormally high prices, and that in some previous years some of the largest constituent companies of that corporation—the Illinois Steel Company, for example—has not only made no profit, but has made actual losses. But again this matter may be brought to the test of census figures. These show that in 1900, which was a remarkably good year, the steel works and rolling mills of Pennsylvania made 13 per cent. on their turnover; those of Ohio, 11 per cent ; and those of Illinois, 11 per cent. These figures do not include depreciation and interest.

In my contribution to the Reports of the British Iron Trade Commission, I have shown that, speaking generally, as compared with the prices that ruled in the years of depression—1894 to 1897—the average prices quoted for American pig iron since the U. S. Steel Corporation came into existence, were 25s. per ton higher, and those of finished materials at least as much again. This higher range of prices was sufficient to leave the Steel Corporation with an increase due to differences of price alone of not less than 20 millions sterling per annum on their gross product. The gross profits returned by the Corporation for the first six months were about 11 millions sterling, so that the inference is that if the prices of 1894-97 had prevailed in 1901, the Corporation would concievably have made no profit at all. This is certainly a possibility that has to be faced If the possibility becomes translated into a fact, the longevity of the Corporation would be likely to be interfered with.

No doubt the private manufacturer in the United States, as elsewhere, often does remarkably well. That, however, is usually due to exceptional conditions of resources, technique, special products, reputation, or administration. And, after all, I am not sure that there may not be firms in this country that can equal the best of American profits in normal times. It is certain that the Carnegie Company is far from being a typical case. I remember Mr. Carnegie himself

some years ago showing me his balance sheet, and at the same time putting before me the then recently published balance sheet of his greatest rival—the Illinois Steel Company. The one showed profits running into millions of dollars; the other made no profit at all. The Carnegie methods had, no doubt, much to do with the success of his firm. Those methods briefly consisted in having the most able and enterprising heads over all departments; in being thoroughly up-to-date in plant and processes; in securing the largest possible output, and always working full time, so as to reduce standing charges; in adjusting prices to the needs or the demands of customers, so as never to miss an important contract; and in playing off one plant against another, and one department against another, so as to secure the best possible results all along the line. Another essentially effective method was that of letting it be known that the race was to the swift—that the man who succeeded could always rely on being rewarded, while the man who failed was no more heard of. There is no magic in all this. The same methods applied here would achieve the same sort of snccess; but no doubt different in degree. Before leaving this subject, I may add that the typical American thinks that we earn our profits very easily, and I have again and again been told that if we worked as hard, and as energetically, as the Americans, we would do better even than they do. It is probable that there are few businesses now yielding profits here that might not be made to give still better results.

In appendix D will be found a statement of the cost of producing rolling mill products in the seven principal States in 1900, with the value of the products, and the resultant profits.

CAPITALIZATION.

In the early infancy of industries the capital embarked was small, and the product was the same. One of the most characteristic phenomena of industrial development has been the progress made in extending the dimensions of limits of production. Every manufacturer is now acquainted with the economic differences of production on a large, and production on a small. scale. In no country, however, are these differences so fully recognised as in the United States. Large works enable the average capital per ton of product to be lowered, and the average annual product per wage-earner to be increased. In the steel industry of the United States, the average capital per establishment was 705,000 dollars in 1890, and 1,008,000 dollars in 1900. This increase of 40 per cent. in average capital was accompanied by a reduction from 37 to 28 dollars in the average capital per ton of annual product, and by an increase from 53 tons to 82 tons in the average annual product per wage-earner, while the average value of the product per wage-earner, despite the considerable fall of prices in the interval, had increased from 2,455 dollars to 3,260 dollars.

These figures point some lessons that are worth pondering, and not least so in a district like that of South Staffordshire, where the works are generally carried on upon a small scale. It would probably well repay the cost and trouble involved, if this Institute were to appoint a Commission to consider what would be the effect on the local iron and steel industries of merging the many small concerns now carried on in the district into a smaller number of large ones. We have seen that the average capital of the individual steel works and rolling mills of the United States is returned by the census at £200,000. The average capitalization of the works of Staffordshire unquestionably falls much below this figure.

SKILLED AND UNSKILLED LABOUR.

One of the most important matters controlling the cost of labour in any industry, and certainly not least so in the iron industry, is that of the proportions of skilled and unskilled labour employed—or put in another form—of highly-paid and low-paid labour. Our American friends claim that they have succeeded within recent years in greatly reducing the amount of skilled labour required in their industries, by the much more extensive employment of automatic machinery. I have before me some official figures which demonstrate the importance of this fact. The President of the Federal Steel Company—now one of the constituents of the United States Steel Corporation—submitted to the Industrial Commission of that country a statement of the number of skilled and unskilled workmen employed by that company in October, 1898, and in August, 1899, from which it appeared that of the total *persónnel* 34 per cent. were skilled and 45 per cent. unskilled, while within this interval the number of skilled labourers had increased by 15·97, against an increase of 22·3 per cent. in common labour. When I add that the average daily wage paid to skilled labour in 1899 was 2·53 dollars, and of unskilled labour was only 1·70 dollars, the economic importance of this differentiation becomes at once apparent. In the case of this particular company, the actual wages of unskilled labour were about £52 a year less than those of skilled workmen, and this amount, spread over a considerable number of workmen, is likely to make a vast difference in the financial results of any industry in the course of a year. It is clearly important to all manufacturers to look into this matter for themselves. It is the interest of everyone to see that no more skilled, or in other words, highly-paid labour is employed than is absolutely necessary. On the other hand, it does not always follow that low-paid labour is cheap labour. On the contrary, there are many cases, actual and conceivable, where low-priced labour is far from cheap. Every case has to be judged on its merits. The ruling principle is, or should be, that if the work can be done by machines that require a minimum amount of attention and skilled oversight, the low-priced labour should generally be sufficient. If, however, the work calls for

initiative, experience, judgment, and thought, then unskilled labour not likely to be cheap at any price. It is the old story of Sir Josh Reynolds and the mixing of his colours. The young artist, envious the effects obtained by the great master, asked him with what he mi his pigments. "With brains, Sir!" was the reply. When work mixed with brains its nominal cost is bound to increase.

BLAST FURNACES.

In one respect the conditions of the blast furnace practice of United States and of our own country, are more or less identical. B countries have greatly reduced the number of both works and furna within recent years. In the United States, the number of works p ducing pig iron decreased from 400 to 278 between 1890 and 190c decrease of 122 works, or 30 per cent. There has been a correspond decrease in the number of furnaces, and briefly, it may be said t to-day the United States turns out three times the quantity of pig i that it did twenty years ago with one half the number of furnaces operation. The average annual output of American blast furna using bituminous coal or coke was then under 20,000 tons a year. day it is about 80,000 tons, and in exceptional cases it consider exceeds that figure This great advance has been largely founded the use of bituminous fuel instead of anthracite coal. Put in another the total daily capacity of 681 blast furnaces in 1888 was 17,000 t whereas the total daily capacity of 399 furnaces in 1900 was 58,000 tons.

The following figures show how the raw materials of the United St iron industry have been cheapened of late years:—

	Average value per ton of materials used in the U.S. iron and steel industries in 1890 and 1900. 1890. Per ton.	1900. Per ton.
Domestic Iron Ore	4·39	2·53
Foreign Iron Ores	6·06	5·44
Coke	3·32	2·64
Bituminous Coal	1·54	1·32
Mill Cinder, &c.	2·69	2·35

THE BASIC PROCESS.

The recent course of the American iron industry has been attende few more striking phenomena than those of the development of the b open-hearth process. Up to within the last ten years, it c hardly be said that this process had made steel in the United St Two works did, indeed, attempt to carry on the manufacture of Besse basic steel at an earlier period, but when I was in the States last y

neither of these plants were working, and it was understood that in both ca-es the process had been definitely abandoned. It was also understood that for a number of years the Carnegie Steel Company had locked up the basic patents so that they m'ght not be allowed to interfere with the vested interests of that period.

If this was the case, the same company have since made amends in the enterprise thrown into the development of the process during more recent years. During the last four years more especially, the American basic steel industry has made very remarkable strides, and there is a widely-shared belief that so far as the open hearth is concerned, it is the process of the future. The great works of the Carnegie Steel Company, the Lukens Works near Philadelphia, the Ensley Works at Birmingham, Alabama, and other plants which I visited while in the United States last year, are all doing good work, mostly with a special mixture which involves a different practice to that adopted in this country, and the conditions of which are described in the recent report of the British Iron Trade Commission. I need not repeat here the facts contained in that Report, which is available to all the world. But I may at least suggest the possibility of American practice, if closely and carefully studied, affording hints that may be utilised in British practice, despite the differences of conditions between the two countries, of which no one can be more fully conscious than myself.

TRANSPORT.

The history of the American iron trade in the last thirty years is in no small part a history of transportation. The cheap carriage of the ore and coal has been the indispensable condition of the smelting of the one by the other. And, clearly, this factor has not been peculiar to the iron industry. The perfecting of transportation has been almost the most remarkable of the mechanical triumphs of the United States. The efficiency of the railways of the United States has been brought to a point not approached elsewhere, largely in consequence of that very competition whose ill effects have been so often felt. The good has come with the evil; and here, as in the whole domain of private property and competitive industry, the problem is how to eradicate that which is bad and yet maintain the good. In the carriage of iron ore and of coal cheap methods of railway transportation, developed under the stress of eager competition, have been utilised to the utmost; and the same is true of the transfer from rail to ship and from ship to rail again, of the carriage in the ship itself, and of the handling of accumulated piles of the two materials. The ore is loaded to cars at the mines by mechanical appliances. At the Mesabi mines the steam-shovel that digs the ore from the ground deposits it in the adjacent car. In conveying the mineral from the mine to the blast fnrnaces, hauls of 800, 900, and 1,000 miles are necessary, with two separate breakages of bulk. It has

been truly said that fifty years, or even twenty-five years ago, this would have seemed impossible on such a scale, and at so low a cost.

In this country, as we all know, one of the most serious items of manufacturing cost is that of transport, whether for raw materials, or for finished products. In the United States, the cost of this item is also quite heavy, but not so much because of heavy charges in relation to the distance covered—which appear to be characteristic of British conditions—as because of the enormous distances over which both raw materials and finished products have to be carried. The greatest centre of the British iron industry is the Cleveland district, where the average length of haul for four-fifths of the raw materials used does not exceed twenty miles The greatest centre of the American iron industry is the Pittsburg district, where the average haul of the raw materials used is not under 600 miles, taking the average of Lake Superior ore at 1,000 miles, and the average of coke, limestone, etc., at 40 to 50 miles. In the Cleveland district the total transportation costs of the home raw materials used per ton of pig iron produced may be taken as 8s. 6d. to 10s., including ore, fuel, and flux. In the Pittsburg district the corresponding total cost may be taken at 12s. to 14s. for iron ores, 3s. for coke, and 1s. 6d. for limestone, etc., per ton of pig iron produced, making up a total of about 18s. per ton of iron, or fully 8s. 6d. per ton more than the average of the Cleveland district These costs vary from period to period according to the freight conditions and the demand.

In most other districts, the costs of transport per ton of pig iron generally take a higher range than those of Cleveland, except at a few of the Scotch works where the local ore is still used, and in which the coal and the ironstone are practically mined on the spot. Nevertheless, the distances to be covered are not in any case such as would be considered excessive, but rather the contrary, in any other country except our own. It is probable that the district of South Staffordshire labours under greater disadvantages than any other, since the local supplies of iron ore are limited, and by no means cheap, while the markets for a large part of the finished products, while geographically close at hand, are, in point of cost, a long way off. There is no important centre of the American iron industry that would not be regarded as admirably situated for foreign trade if located as near to the sea as this district. No such good fortune, however, attends the American iron trade. Even in the neighbourhood of Philadelphia, the ironworks are over a hundred miles from the ocean. while in Pittsburg they are nearly 500 miles, in Chicago nearly 1,000 miles, and in Cleveland, Ohio. and Youngstown (Ohio), they are 550 to 600 miles. Indeed, although you are accustomed to think of yourselves as worse off in this respect than most competitive districts, you are well within a hundred miles, or but little more than one-third, of the distance of the most favourably situated of the iron

centres of the Southern States, and less than one-fifth of the distance of the furnaces of Pittsburg from the sea.

To those who are engaged in the heavy trades of this country, the greatest question of the day, and of the future, is that of cheap transportation. With cheaper transport, you could bring both ores and fuel to this district from within a much wider area than now, while you could also introduce, where expedient, the cheap products of other countries, enabling you to utilise semi-finished steel, in the form of blooms and billets, as furnished by Germany and the United States, to produce the finished forms of manufacture that are disposed of both in our home and in foreign markets.

In order to enable me to place before you some idea of the difference in American and British conditions of transport, I have obtained through my friend, Mr. T. N. Eley, Chief Mechanical Engineer of the Pennsylvania Railroad Company, the annual report of that great corporation for the year 1901. This report shows that the average length of haul for all descriptions of traffic, mineral included, was in that year 104½ miles, or about 8½ miles less than the distance by the London and North Western Railway from Birmingham to London, and about 16½ miles less than the distance from Dudley to London. The members of the Institute will be perfectly familiar with the charges made for transport from here to the Thames, or other shipping centres. The Pennsylvania average earnings per ton carried over the distance of 104½ miles—including all sorts of freight—were only 60 cents, or 2s. 6d., which corresponds to ·26d. per ton-mile. The average cost of the service is given at ·19d. per ton-mile, so that the average profit per ton-mile was only ·10d., or about 38 per cent. This, so far as the Pennsylvania Company is concerned, is all that is left to pay working expenses, interest on capital, repairs and renewals, and everything else that has to come against goods and mineral traffic.

Now let me compare this situation with that of British railway transport. We have here no authoritative record of the cost of working railway traffic. When the Railway and Canal Traffic Bill was before the Board of Trade, I elicited, in the course of cross-examination of the late Sir George Findlay, the then General Manager of the London and North Western Railway, that the cost of conveying a ton of minerals was about one farthing per mile. The average receipts per ton-mile were then unascertainable. But it has since been given by Mr. G. Gibb, the General Manager of the North Eastern Railway, at a trifle over ·9d.—say virtually a penny—for mineral traffic, from which it is to be inferred that instead of being satisfied with a profit of 38 per cent., the British Railways charge a profit of nearly 300 per cent. I think this assumption is all the more justified, because I happen to know that the North Eastern Railway Company is by no means one of the worst offenders in the matter of high charges.

We have seen that the average working cost per ton-mile of the Pennsylvania Railroad traffic is ·19d. Is this very much below the British average, and, if so, why so? I do not doubt that this is a considerably lower figure than British railway working costs can be expected to reach. The average haul on American lines is probably three times that of our own. In 1901 the average number of tons in a Pennsylvania loaded car was about 21 (exactly, 20·83), and the average train load was 489 tons, or at least three times the average of British lines. All this helps a low cost of transport. British railways will never enjoy an average haul of over 100 miles, and their gradients being what they are it is unlikely that they will ever have an average train load of 400 to 500 tons all round.

But they may go much further than they have done in the last-named direction, and in that of economy generally, by introducing a different and a heavier type of wagon, and heavier locomotives; and I am glad to think that the leading lines are now introducing improvements in both directions. It has been more than hinted to me that freighters are not in all cases eager to aid such efforts at reform, and especially owners of private wagons. If this be so, I can only remind you that you cannot both have your cake and eat it.

COSTS AND PRICES.

I propose now to make some reference to the course of prices as affecting the development of the iron industry of the United States, and the conditions of our home iron trade. For the purposes of such a comparison I propose to compare for both countries three different periods, each of them notable as having been influenced by an unusual degree of prosperity, namely, 1880, 1890, and 1900. So far as our own country is concerned, I take my figures from the annual circular of an old and well-known Liverpool firm, Messrs. W. Fallows and Co; while for the United States, I have taken my figures from the Decennial Census Reports. The British figures are the lowest in the several years.

Great Britain.

	1880.			1890.			1900.		
	£	s.	d.	£	s.	d.	£	s.	d.
Scotch warrants ...	2	4	4	2	3	4	2	19	8
Scotch bars ...	6	10	0	7	0	0	8	10	0
Merchant bars, Liverpool ...	5	15	0	6	0	0	9	10	0
S. Staff. List iron ...	7	15	0	9	5	0	10	15	0

United States.

Average price per ton of pig iron produced by mineral fuel in 1880, 1890, and 1900, in Dollars and Cents.

	1880.	1890	1900.
Pennsylvania	25.85	17.28	14.97
Ohio	26.04	16.36	15.73

			1880.	1890.	1900.
Illinois ...	...	...	28·06	15.20	10.23
New Jersey	...	...	24.27	17.21	16.81
Alabama	...	...	22.69	11.65	10.96
W. Virginia	...	...	22.48	17.39	16.57
Tennessee	...	...	17.25	12.38	12.10

An examination of these figures will show that the average recorded value at the furnaces had greatly fallen in every one of the States enumerated over this period, in some cases by more than one-half. The drop in the cases of Illinois and Alabama is more especially remarkable, and not less so because the former State has neither ores nor fuel close at hand, while the latter has both to a large extent within a ring fence. The greatest fall took place between the years 1880 and 1890. Between 1890 and 1900, indeed, there were much lower values than those recorded for the latter year. During 1895-96, there was such a phenomenon as "six dollar pig iron," both in Alabama and in Tennessee. In 1900, however, the average value was given as nearly twice that figure. When I was in Alabama last year I took some pains to ascertain whether "six dollar pig" was merely a "flash in the pan," or whether it was likely to be resumed as a permanent condition at an early date. I was informed by some of the leading men in the district that they did not know of more than one concern—one located a few miles from Birmingham—which could produce pig iron at six dollars; the rank and file could not produce pig iron as a regular commercial product for less than 30s. per ton. The consumption of coke is heavy—about 30cwt. per ton of pig iron—and the furnaces do not yield such a considerable output as those of Pennsylvania, 800 to 1,000 tons per furnace per week being regarded as an excellent average output. The Southern States are, moreover, remote from their principal markets. They are about 260 miles from their nearest shipping ports—Pensacola and Mobile—and twice that distance from their nearest inland markets of importance. The present rate for export is rather over a farthing per ton per mile, and unless they get it reduced below that figure—which it is proposed to do by improving the navigation of certain rivers (the Warrior Cooza and Alabama) so as to connect the Tennessee River with the Gulf of Mexico—there is not much liklihood of lower rates being secured. I am, of course, aware that the ocean rates are often nominal, but that is a condition which can only be expected at certain periods, and then somewhat irregularly.

CONCLUSION.

There are many features of American practice, applicable more or less to British conditions, which I have not touched upon for lack of time. But I have probably suggested sufficient material for a discussion of the differences in the circumstances of the two countries that may lead to useful results. I would instance as matters that might be profitably

considered on a future occasion, the subjects of Ocean *versus* Lake freights, and of Canal *versus* Railway transport, as affecting conveyance, and those of the more general use of labour-saving plants, such as charging machines and electric cranes, etc., in steel works, and automatic plants at blast furnaces. Many other differences of conditions and practice are dealt with in the recent Report of the American Commission of the British Iron Trade Association, with which many of you have, no doubt, already made yourselves familiar, and to which I would veuture to refer those who have not.

APPENDIX A.

Average wages paid to all hands employed in the Iron and Steel Industries of the United States in the census years 1890 and 1900 :—

	Average earnings per annum in Dollars.	
	1890	1900
United States	445	477
Pennsylvania	457	504
Ohio	472	561
Illinois	640	725
Alabama	395	272
Virginia	414	348
Tennessee	447	247

APPENDIX B.

Rolling Mills and Steel Works in 1890 and 1900—members employed and average wages paid.

	1890.			1900.		
STATE.	No. employed.	Wages paid. 1=1,000 Dols.	Average annual wages. Dols.	No. employed.	Wages paid. 1=1,000 Dols.	Average annual wages Dols.
Pennsylvania	76,609	42,356	552	94,664	53,817	568
Ohio	19,489	11,405	585	27,638	16,443	594
Illinois	7,265	4,324	595	13,632	7,464	547
New Jersey	4,498	2,301	511	7,699	3,600	467
Massachusetts	5,168	2,454	475	6,099	3,401	557
Alabama	1,696	682	462	2,204	1,072	486
West Virginia	3,346	1,552	434	3,975	2,066	519

APPENDIX C.

Average wages paid in 1900 and in 1890 at Blast Furnaces using mineral fuel, in leading States:—

	1900.			1890.		
	No. of hands. 1=1,000.	Total wages. 1=1,000 Dols.	Average per ann'm. Dols.	No. of hands. 1=1,000.	Total wages. 1=1,000 Dols.	Average per ann'm. Dols.
United States ...	37·4	17,849	477	30·1	13,416	445
Pennsylvania ...	15·9	8,015	504	15·4	7,047	457
Ohio	5·8	3,257	561	3·8	1,795	472
Illinois... ...	3·0	2,176	725	1·4	896	640
Alabama ...	4·8	1,306	272	3·3	1,305	395
Virginia ...	1·5	523	348	1·1	456	414
Tennessee ...	1·4	347	247	·8	358	447

APPENDIX D.

Average cost of production of Rolling Mill products and profits therefrom, in 1900 (in thousands of dollars).

STATE.	Wages. 1=1,000 Dols.	Miscellaneous expenses. 1=1,000 Dols.	Cost of materials. 1=1,000 Dols.	Total expenses tabulated. 1=1,000 Dols.	Value of products. 1=1,000 Dols.	Amount of profit. 1=1,000 Dols.
Pennsylvania	53,817	14,573	218,860	287,250	332,588	45,338
Ohio	16,443	3,134	67,785	87,362	98,568	11,206
Illinois	7,464	2,516	30,020	40,000	45,149	5,149
New Jersey	3,601	1,056	14,322	18,979	21,835	2,856
Massachusetts	3,402	989	7,491	11,882	13,412	1,530
Alabama	1,072	108	2,451	3,631	3,905	274
West Virginia	2,066	166	8,729	10,961	13,394	2,433

THE DISCUSSION.

Mr. Walter Jones: It was my pleasure to listen to an address by Mr. Jeans upon a somewhat similar topic, in Birmingham, last Thursday and the Thursday preceding. Upon these occasions he dealt with the topic in what may be termed its general aspects, and to-night I am pleased to find it is more specific. He has to-night given a number of figures which many would do well to read, mark, learn, and inwardly digest. In one or two places he touches upon water transport, a matter which our President has often referred to; and I was struck with the difference in railway freights between this country and the States. Unfortunately, the railway companies of Great Britain do not pay very big dividends. If they pay 4 instead of 3 per cent. it is considered a good year. If they made large dividends, I think the traders would have the right to exert very strong pressure upon the railway companies. But even as it is, there is plenty of scope for reduction in the cost of transport of heavy goods from the Midlands to the sea coast.

Mr. Le Neve Foster: I, too, had the pleasure of listening to Mr. Jeans's two addresses before the Birmingham University, and as I understand they are going to be printed, my advice is that those who were not present should at least read them. Mr. Carnegie remarked, some time ago, that we should look to our home trade. And I think that is more particularly applicable to Staffordshire. We are not on the seaboard, and therefore we want to make such home products as will be particularly useful to the home trade. We are in the best situated place in the country for our home trade, and it is by our home trade that we can principally live. I don't say—don't trouble about export business at all; but let us try chiefly to make material suitable for home use. We have the cheapest transport to various places in this country because we are in the very centre of England. There is no doubt we are hampered to a certain degree, not only by the Board of Trade, but also by our big engineers, because they issue specifications which are not always applicable to the material made in this country. There is, for instance, a great prejudice against the use of basic steel, and yet basic steel is the product which we ought to foster, because it is made entirely from home ores. Yet our Board of Trade will not allow basic steel to be used, and they will not even experiment in trying to prove whether it is useful or not. We have, however, enough experience about it to know that it can be produced, I won't say better than acid steel, but at any rate equal to any acid steel that has ever been made. We do not want to import material from Germany, and to avoid this we need a large central works, owned by the various ironmasters of the district, so that they can supply themselves with steel blooms and billets. I can confidently say that it is possible to produce in this district steel blooms and billets at a cheaper

rate than that at which they are being imported into this district at the present time from Germany. I can show figures which prove that it is possible to make steel in this district, at a profit, as cheaply as anything sent from Germany at the present time, and I am willing to show such figures to any members who are interested, if they will ask me. Mr. Jeans says that it has been hinted that traders are not always eager to aid the railway companies in their reforms. Now, with regard to large trucks. Within the last twelve months I have had a number of 12-ton trucks built for my own traffic; but it was months and months before I could get the railway companies to allow me to use those trucks. They hampered me in every direction, and yet it was for their own benefit that these trucks were being built, because it was a saving of tare. For the last two years I have offered to build 20-ton trucks, yet it is only within the last fortnight that they have allowed it. And still the railway companies wish to blame traders for traffic difficulties. I don't think that is fair.

Mr. W. Moore: We have had a most encouraging paper to night. As a rule, when we have been talked to about America and Germany we have generally gone home feeling that we were pretty much "done for." But to-night I think we have been encouraged. With regard to American and Continental competition it has been my opinion that we have looked too much on the black side of things for many years past. English blast-furnace owners could produce pig iron at 28s. or 30s. a ton fifteen years ago at a profit. If that was so then, why cannot we do the same again? Of course, the price we have to pay for fuel, because of miners' wages, is an important matter which has to be taken into consideration now, but miners' wages are uncertain, and it is possible that the cost of pig iron production may again go down to what it was then. I think pig iron has been made at that price in this district, and I have myself seen it done in the North of England. The actual labour cost of making pig iron in the Middlesborough district is 2s. 6d. per ton, so that even if the Americans could make it for nothing in labour, they should only be 2s. 6d. per ton better off than we are. As to American practice and work being so much better than our own, I have no doubt they have better machinery then we have. We ought to be in the same position, and I am very happy to see that at some works there is an attempt to get into as good a position. Six or eight years ago I know they were making pig iron at 28s. a ton in Tennessee. Even the Americans often get stuck fast. I know of one case where a friend of mine, an Englishman, was suddenly sent for to see if he could put them right. Through his exertions the place has been kept going and is going to-day. When they can get down to as low as 28s. a ton in America, and we can do the same here, surely we should be able to live. We can make pig iron, under ordinary conditions, as cheaply as they can. This country is splendidly situated in every way, no part of it is

very far from the sea, and no part is remote from raw materials for smelting, I have never taken a black view of American and German competition. If they like to send stuff over here at what seems to be a low price we should be fools if we did not buy it. Users must be in a better position if they are able to get materials cheaply than if they had to give higher prices for them. I don't think there is anything to be afraid of in foreign competition. We have only to put our shoulders to the wheel and do our best, and introduce machinery suitable for our requirements and cheapen the cost of producing the raw materials.

Mr. H. B. Toy : We are greatly handicapped by railway rates in the Midland district. Sometime ago, I asked the railway company to quote a special rate for a large piece of machinery. The quotation did not arrive until too late, and the order was lost to this district in consequence. The statement that rollers can be trained in a few months is ridiculous, if it refers to sheet rolling with all its variable conditions of contraction and expansion. It may, perhaps, be possible in bar rolling. It is one of the most encouraging papers I have heard read for some time.

Mr. W. Moore : May I be allowed to add something to my previous remarks. I believe the railway rates question in this country is to a great extent in our own hands. If we can get great bulk we can have low rates. As to other expenses, the cost of a great deal of the raw materials has been far too high. Going back to 25 years ago, I find that the ordinary stone on the surface of the land in a certain district was charged up to 2s. 6d. per ton royalty, although it contained only 28 per cent. of iron. It cost 1s. to get it, so that altogether we had to pay 3s. 6d. You can scarcely credit having to pay 2s. 6d. a ton as royalty for simple ironstone got at one shilling per ton. Yet even under these conditions there was a profit on the pig iron made. Railway rates could be reduced if consignments were made larger; but this can only be done by a combination of the people who use the ore.

The President : I can only reiterate what has been said as to the value of this paper, and as to how much we are obliged to Mr. Jeans for contributing it. With regard to acid *versus* basic steel, I don't know that we can go into that question very fully, but I must say that the public generally, and our own Government also, will be some time before they are persuaded into the belief held by Mr. Le Neve Foster. I know it would be almost high treason for me to ask either the Government or my private customers to accept basic steel for steel forgings. The Government look with very great suspicion upon steel generally, and I must say, from my experience up to now that I cannot agree with Mr. Le Neve Foster's idea that basic steel is as good as acid. I shall be very pleased if he can make us some as good. We have had another instance to-night of the way in which railway companies treat traders, and I feel more than ever the necessity for a waterway from Liverpool to

Birmingham and then down to Gloucester, in order to bring the railway companies to their senses. If the large employers of South Staffordshire would act together and make this thing a reality instead of only talking about it, it would be a great benefit to the iron trade. With regard to railway trucks the difficulty lies with the railways. They do object, and object very strongly, and why they should do so I cannot imagine, because we know, if you have a very heavy weight to send—say from 10 up to 15 or 20 tons—they find you a large truck and they take it for you; but there is this about it—they take care to charge you extra; a matter which handicaps us again in these inland districts. If the railway companies were more considerate to the manufacturers of this country there would be a better state of things in Great Britain than there is to-day. I am sure, sir, we are very much indebted to you for this valuable paper. Everyone ought to go carefully into these figures and make the best use possible of such valuable information.

A vote of thanks to Mr. Jeans was carried with acclamation.

Mr. Jeans: There are one or two points that perhaps you will expect me to deal with in answering what has been said during the discussion. The first point is, I think, the question of basic steel. My friend, Mr. Le Neve Foster, and the Chairman, have not expressed exactly the same views on that subject, and I am afraid there is a good deal of difference of opinion in this country as to how far it is, as yet, safe to make use of basic steel for purposes in respect of which a very considerable amount of special strength and reliability are needed. At the same time, as you all know, in Germany and the United States there seems to be no apprehension as to using basic steel for every conceivable purpose. It seems to me that it is really a case for the steel makers and users of steel to bring pressure to bear—first to get the right sort of material supplied, and next to induce the Government departments and other large consumers to adopt that material. I am not aware that that has yet been done upon anything like an organised scale, and of course the individual maker would not be likely to count for nearly as much as a combination of makers. As to German billets, two nights ago I was taken severely to task by a manufacturer who imported German billets. He did not wish to have the home market secured to us so far as German billets were concerned. So there are, you see, differences of opinion among people on this question. One man who is a maker of billets does not like German billets to come in here, but the user of billets (especially when home billets are dear) is only too glad to get foreign billets because they are cheap. I agree that there is a good deal of scope in this district for a plant which would devote itself almost entirely to the manufacture of blooms and billets upon a large scale, in order to meet German competition. Something has been said as to the comparative attitudes of the railway companies and the traders with respect to the size of the wagons and other conditions of transport. I

myself have found that both railway companies and individual traders have been for and against these so-called reforms. Only last night I was sitting at a dinner in London next to the chairman of one of our great railway companies, and we had some conversation upon the movement for employing larger wagons for mineral traffic, and he told me their line had attempted to introduce large mineral wagons a considerable time ago, but they did not find them answer. He also told me that their line was not a large mineral line and that, therefore, the conditions which would apply to large mineral lines would scarcely apply in this case. With regard to general goods and merchandise traffic, he said their average wagon load was only about 2¾ tons. Now you will find in my paper that on the Pennsylvania Railroad the average train load is nearly 500 tons, and the average wagon load is about 21 tons. Against that you have in this country a leading line, which may be typical, with an average wagon load of only 2¾ tons. But that is not a mineral carrying line to any large extent, whereas the Pennsylvania line *is* a mineral line. At the same time an average wagon load of only 2¾ tons, when the average tare of the wagon cannot be less than 5 or 6 tons, is a sort of thing which ought not to be allowed to continue.

Something has been said as to the comparative conditions of cost in the two countries. I think if you refer to the *Iron and Coal Trades Review* of yesterday, you will see some rather interesting information on that subject. In the first place, you will remember that five or six years ago Connellsville coke was sold at 90 or 95 cents per ton at the ovens. "One dollar coke" was spoken of as a regular thing at that time. I am speaking of 1895 and 1896. The parties concerned in the Connellsville region have now entered into a stipulation to sell no coke under four dollars per ton for next year, and the cost of Lake Superior iron ores is being kept up at corresponding figures. I think it is some consolation to British iron and steel makers that if these figures are adhered to during the whole of next year (which is the contract) we are not likely to hear very much of an invasion of American iron and steel into this country during that period, because I don't think it would be possible with four dollar coke, and, possibly, four or five dollar Lake Superior ore at the furnace, to produce pig iron at Pittsburgh at under 50s. per ton. On the other hand, you must bear in mind that the United States Steel Corporation controls the bulk of those supplies, and that the coke does not cost them all that—except in so far as they must charge to the credit of the coke ovens and mines certain high prices in order to meet their enormous capital obligations. There is another matter which is really very important and I think it will be an additional crumb of comfort to this meeting. Two or three years ago some private traders purchased in the Lake Superior district some ironstone mines for half a million dollars. Those same mines were sold the other week to a new steel-making trust for five million dollars. In other words, in so far as the capital value of those ores are concerned they have, as

influenced by this transaction, appreciated about ten times compared with what they were worth about two years ago. Well, now, if that sort of thing is going on, gentlemen, you can easily understand that raw materials must become much dearer in the United States. In fact they have already done so, and they must become permanently dearer, unless these big companies are to go into the bankruptcy court. And of course if raw materials are to be dearer, the dangers we have been fearing in the way of American competition assume a much less formidable shape. I am very glad to hear that some of the railway companies are willing to carry at one-third of a penny per ton per mile. I must say, that, except for very long distance traffic, I have not met with such low rates; but we all know that mineral traffic carried on a large scale for anything between 70 and 100 miles can be carried at that rate and yet pay a reasonable profit. Mr. Jeans concluded by acknowledging the vote of thanks passed to him for his paper.

The President: I should like to draw Mr. Jeans' attention to that figure of $2\frac{3}{4}$ tons as a truck load. We complain that ores, coal, ironstone and pigs are charged at too high a rate. The larger loads, say 14 or 15-ton truck loads, must cost less to handle, proportionately, than such small loads, yet no reduction is made to the trader.

The Fourth Meeting of the Session was held at The Institute, Dudley, on Saturday, the 17th of January, 1903.

THE PRESIDENT (Mr. WALTER SOMERS, J.P.) in the chair.

The minutes of the previous meeting were read, adopted, and signed.

Messrs. A. E. Guest and James W. Shenton were elected members of the Institute.

THE PRESIDENT introduced Mr. HERBERT STONE, F.L.S., F.R.C.I., who read the following paper :—

THE UTILIZATION OF PIT TIPS FOR THE GROWING OF PIT TIMBER.

By HERBERT STONE.

It is a little more than eight years ago since attention was first called to the possibility of utilising pit tips for the purpose of producing timber. Sometime prior to the Autumn of 1894, Mr. W. R. Fisher, one of the Professors of the Royal Engineering College at Cooper's Hill, Surrey, during a visit to the Ardennes, was struck by the fact that in several localities the ancient spoil heaps were covered with rtees that in some places grew quite close to the workings; even some of the slag heaps adjacent to the iron furnaces had vigorous sycamore and ash growing upon them.

It occurred to Mr. Fisher that an enquiry into the conditions prevailing in our own Black Country might be productive of good, so he induced Mr. Stafford Howard, one of His Majesty's Commissioners for Woods and Forests to accompany him upon a tour through this neighbourhood. The visit was entirely informal, and no Official Report upon the Inspection has appeared; but an account of it from the pen of Mr. Fisher appeared in the columns of the *Daily Chronicle*, some time in August, 1894. Comments upon this article appeared in other papers, notably one in the *Spectator*, of August 25th, 1894. The pith of the Commissioner's conclusions is that there are 14,000 acres of waste land in the Black Country of the Midlands which are suitable for the growing of trees. This, from a man who has not only the care of a large acreage of forests, but whose business it is to provide for the forests of the future by planting, backed by the opinion of Mr. Fisher himself, is of considerable weight.

I doubt if ever a stranger has travelled through tha Black Country, either by road or rail, who has not deplored the desolation which meets the eye upon every hand. In fact, the district has become a by-word and a subject for cheap jests. For my own part I do not marvel half so much at the dismal landscape as at the complacency with which the inhabitants are content to leave it so. However, I am not here to make invidious criticisms upon the people of the Black Country, but to appeal to their commercial and to their æsthetic sense. I am, I hope, too much of a business man to appeal to the latter alone, because that would entail sacrifices for the benefit of posterity, which could only be responded to by the few, whereas, if anything but a trifling result is to be ootained, it is by wide co-operation of a large number of people spread over a long period of years, which cannot be hoped for unless their

enthusiasm be leavened by pecuniary interest. To all to whom the thought has occurred, that a large portion of the Midlands amidst one of the most populous districts in England should be abandoned as worked out, used up and useless for any purpose whatever, thrown aside like an old garment as entirely done with, there seems something like despair in it. Is land only good for minerals beneath, and for the storage of rubbish upon the surface? I am aware that attempts have been made to bring certain places into cultivation without success, and one failure no doubt does much to discourage further attempts; but land which may be utterly unsuitable for the cultivation of crops may be eminently adapted to other purposes. It is a well known fact that trees will thrive in soils and situations where it is hopeless to expect other crops to grow, and the success which has attended the attempts to re-afforest some of the mountain sides of the Alps by the French Government shows what can be done with materials much more unpromising than pit banks.

I wish it to be understood that I do not refer to clinker heaps nor slag heaps under the heading of my paper. The title, of course, excludes them, but I have met many people unfamiliar with the Black Country who confound the three kinds of heaps. Slag has a marketable value; but I am not sufficiently versed in these matters to know whether the slag is extracted from old heaps for the purpose of grinding up into manure, or whether it is only that which comes straight from the furnace that is dealt with. In the latter case so much the better for our purpose, for we can then include slag heaps amongst our promising situations, as they can provide phosphates in such profusion as to be simply ideal ground for the growth of trees. Iu support of this, we have the statement of Mr. Fisher that he saw trees in the Ardennes growing upon heaps of glassy slag. As regards clinker, I admit that we have here a soil which is, to say the least, discouraging; but I am told by Mr. Tucker that the mounds are gradually disappearing, being converted into ballast for the use of the railways.

Slag and clinker heaps may then be allowed to work out their own destiny. If they be cleared away, and the ground thus levelled, I do not doubt but that the latter will eventually be brought into cultivation. It is, therefore, only the mounds of spoil gained from the pits which seem at present so hopeless. They consist chiefly of shale in different stages of decomposition, from large, hard lumps, to very fine dust, which, when dry, may readily be raised by a puff of wind. At their bases accumulate the finer particles which have been washed down by the rain, and for some distance around is usually an open plain. If the mounds were all lumps, or all finely disintegrated particles, the cases would be unpromising; but the small stuff is mixed with the large, the whole forming a loose, well-ventilated soil accessible to both rain and air. This soil is neither so bad in its physical constitution as that of the

red marl, all pebbles with scarcely sufficient sand to hide them, such as we see in abundance in the Midlands, nor as those heavy clays which "run together" in wet weather and crack in the drought, as we find in many other fertile parts, in Gloucestershire for instance.

As regards the chemical composition of the soil of these tips, I think I cannot do better than leave this to my friend Mr. Tucker, who has kindly promised to support me this evening. But, from my own rough tests I cannot affirm that there is lime in much abundance, hence we shall have to draw our conclusions from the actual experience of growing trees upon them to satisfy ourselves that there is sufficient lime present to enable trees to support life. Examples which demonstrate that there is a sufficient quantity of all the chemical substances needed by plants may be found in the modest covering of grasses, coltsfoot, and other weeds which may be met with on all these waste lands. Where grass will grow trees will grow also. Further, there are oases to be found in the Black Country, where pit banks have been cultivated into gardens, notably that which is now Wednesbury Park, where quite a vigorous growth of trees has rewarded the efforts of the gardeners. I do not wish to lay too much stress upon these cases, because from the very nature of the undertakings we must conclude that much more care has been spent upon them than can be claimed for trees to be grown at a profit, besides which there has no doubt been a certain amount of manure put upon the ground in the first instance. We cannot afford gardeners or manure for forestry, so that truly convincing examples can only be drawn from successes gained under identical conditions. Of these we have the evidence of Mr. Fisher upon the trees in the Ardennes, and nearer home the planting which has been done upon similar pit tips in the Forest of Dean under the enlightened superintendence of Mr. Philip Baylis. I am sorry that I have been unable to provide photographs of these spots in time to utilize them as illustrations to this paper, but Mr. Baylis's testimony may perhaps be of sufficient weight by itself. He writes me as follows :—" I have had two or three tips planted with larch, and the trees which have been planted some six years are now making splendid growth. I can find instances of three feet growth in the year, and the great bulk of the trees doing well. I think the birch also will thrive on pit mounds."

In a letter recently received from Mr. Fisher, he informs me that he recently saw some birch and sycamore growing on the refuse heap of a coal pit near Valenciennes. Another friend to whom I wrote for information as to the state of affairs in Scotland, told me that though he could not mention any spot where trees were growing in such situations, yet he remembered that it was currently accepted amongst the children that the biggest blackberries were to be found upon the bushes growing upon the old pit mounds. I have also testimony from the Commissioner of Woods and Forests above referred to, who wrote me in November

last:—"I see no reason why the local authorities should not acquire and plant up some of the disused spoil heaps (provided there are no fume-emitting works close by) with success."

A further objection which has often been urged is that the atmosphere of the Black Country is too impure to permit trees to thrive. I do not think that this is valid at the present time, nor do I think that at any time it was generally true. The evidence of your own trees in the grounds of Dudley Castle are sufficient answer, as they have survived the effects of the Black Country air very creditably. At the same time I do not recommend the selection of localities exposed to the drift from brickworks and the like. There are plenty of places to be found, where, unfortunately, no industry appears to be sufficiently thriving to provide fumes enough to kill anything.

To sum up, we find that we have conditions favourable to the growth of trees in the three essential respects, *i.e.*, suitable physical condition of the soil, sufficient of the indispensable chemical elements present in that soil to nourish plants and an atmosphere for the most part innocuous if not of the purest. A fourth condition is also in our favour, namely, that the soil of the pit banks, instead of being a few miserable inches deep, such as we find above the Keuper Marl in Sutton Park, or even at Dudley Castle, we have in the soil of the pit tips a depth attained by no other surface soil that I am acquainted with. Again, if we had to deal with recently-made mounds, we could not expect them to be anything but sterile, but the disintegration of the shale implies the action of the rain, and the addition of rain to a soil implies in its turn, that the rain has left within the mounds a store of ammonia which has been accumulating for years. It has been computed that 21¾lbs. weight of nitrate of ammonia is annually brought to an acre of land by the rain and snow. No doubt most of this would be carried off by the water which runs off the tops of the mounds, but it would still be found in the fine earth at the foot and in the hollows

I think I have said enough to justify my contention that re-afforesting the pit mounds is within the bounds of possibility, but I have still to refer to the flat land lying waste around them. I do not know sufficient of any area to say what was the condition of this land before the pits were opened. I hope to gain some information upon this point to-hight, but it is not rash to assume that prior to the discovery of coal the land would be utilised in agriculture precisely as it is in other parts of Staffordshire and Worcestershire. Has it suffered any injury since that time beyond neglect and want of cultivation? If it has not, then surely we may hope to begin where the ancient cultivators left off, having on our side the advantage of the accumulation of nitrate of ammonia during generations, and on the other hand an atmosphere rather less pure. Whatever arguments may

be urged against the growing of trees upon the mounds themselves with this unimportant exception, nothing can be brought against the planting upon the adjacent land. We could well afford to let the mounds take care of themselves, if we can once succeed in getting the tree planting done around them. They would soon be hidden, and so the æsthetic sense wonld be satisfied, and, after a time, the trees would seed themselves just as the grass has already done, and the heaps would cover themselves with young trees without trouble from the planter.

The æsthetic sense is, however, by no means the one to be satisfied. I am strongly of opinion that a reform to be widespread must at least pay interest upon money. Much must here be left to conjecture, for we have no data whatever to guide us in estimating the probable return from the planting of trees upon this soil or in this district. Many can be found who say that it will not pay to grow timber anywhere in England however low the rent of the land may be, and even those who admit that it can be made to pay rent and interest upon outlay, will not admit that there is any profit to be obtained, added to which there are very few to-day who are willing to wait twenty or more years before they see some return. This is the greatest drawback of all, as it almost excludes hope of private effort, and unless some of our wealthy landowners who have gained their fortunes from beneath the soil are willing to mingle a little public spirit with their enterprise, we have only the public bodies to look to for the improvement we seek. As far as the landowners are concerned, I mean those who have either drawn royalties from the mines, or have exploited them themselves and have caused the land to become a wilderness in the pursuit of wealth, I think it would be a gracious act if they would make some little sacrifice in order to clear up the mess they have made.

The public authorities stand in another category which divides itself into Imperial and Local. I fear that we cannot hope much from the Imperial authorities, because our Commissioner, Mr. Howard, who is spoken of by the *Spectator* as the "sympathetic Commissioner," says in his letter to me that "he came to the conclusion that it was not a matter that could be well undertaken by this (the Woods and Forests) Department." In addition to this, upon the appointment of the Committee to inquire into the practibility of re-afforesting the waste lands of the British Isles, I wrote to the secretary praying that the Committee would not overlook the claims of the Black Country; but although ten months have since passed, I have heard nothing whatever of the matter since I received the promise that my letter would be laid before the Committee. Perhaps I ought not to despair before the Committee has completed its labours, but it is a case of hope deferred. If we could find a sympathetic member of Parliament connected with the district, who would interest himself so far as to button-hole a few of the members of the Committee, and ask them to consider the claims of our district at least as sympathetically as those of any other, I think it would not yet

be too late for something to be done. If there should happen to be any such Members of Parliament amongst my hearers, I fervently hope that I shall succeed in making a favourable impression upon their minds.

Turning to the other string to our bow, let us consider what we have to expect from the Local Authorities and what we have to offer them. It is the recognised duty of all such bodies to improve their neighbournoods; but one can hardly expect such an authority to improve those portions of its domain which happen to bear the smallest population, so that what we are entitled to *expect* from them may be put aside. On the other hand, every public body desires to see the rateable value of its land increase, a result which would follow the planting of woods more quickly than by any other means. The rateable value of town property increases, no doubt steadily, but very slowly, and re-assessments are not lightly entered upon, but I understand that much of this land is derelict, and that little of it pays rates.

Imagine then, the course of events subsequent to the planting of a wood. After the lapse of the first three or four years we should have a pretty plantation of trees about shoulder high, which in a year or two more would have grown enough to shut out of the view of the pedestrian all those eyesores which we now deplore. The enterprising builder would by then have realised that dwellings of the better class would be much sought after in the vicinity of the wood, and our manufacturers whose business requires that they should live within easy reach of their factories, would be delighted to avail themselves of such houses in so attractive a spot; for a wood is a beautiful thing anywhere, and in the midst of the Black Country would have a value far greater in comparison. This is now the rate collector's opportunity, for the land from which no rates can now be collected would, in the course of ten years or so, become the West End of the district in which it happens to be situated. Here, by-the-way, we have a still greater inducement to the owners of land, as the money they spend in the raising of trees will be repaid tenfold by the enhanced value of the adjoining land for building land.

The trees themselves form a minor source of revenue, which is, however, not to be despised. If planted as thickly as they can grow when seedlings or plants of two or three years' growth, they will run up perfectly straight in a continuous mass of foliage which will shade and kill all the lower branches, and the weaker trees, so that only the most vigorous will survive; that is to say, that a natural thinning process goes on all the time, and all the growth is forced into the tops of the trees, which grow rapidly in height. This is the first result we wish to arrive at. When the trees are as high as it is judged necessary, say twenty-five to thirty feet, which in some plantations has been attained in the course of twelve years, artificial thinning may then be resorted to, partly in order that the trees selected to remain may receive more light, develop lateral

branches, commence to put on more wood and increase in thickness instead of in height; and also in order to gain a first return for the outlay by the sale of the poles of the trees removed to make room for the others. If the choice of the species to be planted is a judicious one, these poles when only two inches thick at the butt will readily find a sale in Birmingham and elsewhere at from 24s. to 30s. per ton; but if conifers only are planted, as is certainly recommended by most authorities on forestry, no return can be expected until the poles are large enough for pit timber, except from the almost negligible value of the thinnings as firewood. With a fair amount of luck, the trees should be large enough for pit-props in the course of fifteen to twenty years. You know more about the market value of this class of timber than an outsider can; but I think I am not far wrong in saying that pit-props sell at from 17s. 6d. per ton at Cardiff, and on one occasion within the last twelve months, fetched as much as 27s. 6d. per ton. Upon this, railway carriage has to be paid, about 8s. 1d. per ton, bringing the price delivered in the Black Country to the very respectable minimum of 25s. 7d. per ton. Now this is a very good price for young stuff, and surely if it pays the French exporter to ship pit-props to Cardiff and pay freight and dock charges for a return of 17s. 6d., surely it will pay you to grow the same wood close to your own doorstep, with a margin equal to the freight, railway carriage, etc., in hand. It would be worth while considering whether pit-props should be the only product. You are certain of a market for them in unlimited quantity, and conifers, like the Scots fir, are a hardy and reliable crop. I strongly favour a mixture of this species, with sycamore, for as we have heard, sycamore thrives well upon pit tips in two localities, it has a marketable value in the form of small poles and a very much higher value as soon as it affords logs which measure not less than nine inches in diameter at the top. When the Scots fir is large enough to sell for pit timber, it could be cut while the sycamore could be left standing to remain until it is of good size. Sycamore is one of the fastest-growing of our indigenous trees. At Cooper's Hill, where a number of model forests have been planted for the instruction of the students of the Royal Engineering College may be seen a plantation of sycamore planted eleven years ago, which is of an average height of twenty-five feet. These experimental plantations consist of a number of different species all planted at the same time. The two pointed out to me as having made the best growth, were those of sycamore and larch, which, according to Mr. Baylis, will also thrive on pit tips, so that we have the choice of another of the fastest-growing trees tor our purpose, which will fetch a better price than those conifers which are grown simply for the purpose of mining timber.

The planting of a forest is by no means an expensive matter. Young trees can be purchased at an astonishingly cheap rate, and they take no more labour in planting than cabbages, and less attention afterwards. Nevertheless, there is considerable art in the planting and in the choice

of the time to put them in, and it is quite essential that an expert forester should be employed upon the work. A gardener is of no use whatever in this work. He will plant a wood after the same fashion that he would plant a gentleman's shrubbery, in a similar way to the plantations in Sutton Park, where in one spot that I could indicate, there as nearly as many dead trees as live ones, and no prospect of the remainder ever being good for much. With proper treatment, trees will grow in the most unpromising situations, providing that the conditions be thoroughly understood by the planter at the outset.

One essential which is important and which will add to the preliminary expense, is the necessity of excluding the Hooligan. You will be free from rabbits, the great enemies of young trees, but instead you will possibly have the Hooligan, who is the next greatest danger. The outlay upon barbed wire will enhance the cost of laying out the ground and will reduce the profits, but all unauthorised persons must be rigorously kept out of enclosures of young trees or success is impossible.

To recapitulate. We have every reason to believe that all the conditions essential to the proper growth of trees are fulfilled in the case of the pit tips, and more than fulfilled in the case of the adjoining flat lands; that the re-afforesting of the waste lands of the Black Country will be accompanied by the enhanced value of land and of increased rateable value; that if forestry will pay anywhere it should pay close to the market; that the species most suited to the market and most likely to thrive on the pit mounds, are at the same time those which grow fastest and which promise the quickest return; that the Black Country may become a Green Country and present eyesores may disappear, and that all those who are instrumental in carrying this idea to a successful conclusion will receive the grateful recognition of their fellow countrymen.

THE DISCUSSION.

THE PRESIDENT: I am sure you have heard this paper with very great pleasure. We know what great areas of waste land we have, and if timber can be grown upon it, the market is here. The matter is well worth the attention of those large landowners who at the present moment do not receive anything from many hundreds of acres of surface land, and judging from what Mr. Stone says, there is a good prospect of timber being grown. I do hope the paper will reach some of the principal owners of the land, and that they will, at any rate, make a start so that the land will be made use of.

Mr. ALEX E. TUCKER: I think I may congratulate myself on having been instrumental in bringing Mr. Stone this evening, and I congratulate this Institute on the importance of the subject discussed in his paper.

The subject is somewhat foreign to iron and steel manufacture, but I conceive it to be a most fit one for the consideration of our members, who are in a position to influence the various authorities of this district. Before moving the resolution which I shall propose, perhaps I may be allowed to explain my connection with the matter. Some nine years ago I was in company with Professor Fisher of the Woods and Forests department of Cooper's Hill College, and we discussed the planting of slag and other tips. We had both seen successful cultivation of such tips, and the Black Country was discussed. As a result of Prof. Fisher's interest, Colonel Howard, H.M. Commissioner of Woods and Forests, came down to Birmingham to see me. We went over the district together and we took photographs of the desolate tracts of mounds and tips. I know nothing of forestry, nor did I at that time know anyone in this district who could take the lead in the matter. Meanwhile Colonel Howard reported that the subject was not one which he could advise his department to take up, the tracts being too small and too scattered to allow of it being made an Imperial matter. The scheme, therefore, lay dormant until a few weeks ago, when I had the pleasure of listening to an admirable lecture by Mr. Stone. In the discussion which followed, he said he had been looking for me as Professor Fisher had given him an address which was wrong. I, therefore, advised Mr. Stone to read a paper before our Institute.

We have in Mr. Stone a remarkable example of the success attending the consistent pursuit of a hobby. Mr. Stone is not connected with forestry or timber in any way commercially, but so successfully has he pursued his hobby that he is now one of the expert advisers to The Imperial Institute on timber. We have, therefore, in Mr. Stone a gentleman eminently qualified to take the lead in the proposed scheme, and I understand from him that he is prepared to devote his time and his knowledge to the matter. All he asks is that you should support him in any way you can. I am aware that this Institute cannot, as an Institute, take active interest in the required work, but I ask that it shall lend its support to the recommendations contained in Mr. Stone's paper. This leads me to the resolution which I wish to submit, *i.e.*, "That a "small sub-committee be formed to take such steps as this Institute "may deem desirable in promulgating the scheme for cultivating the "tips and desolate tracts of the district." As to the desirability of the scheme there can be no doubt. We are told that we are creatures of our environment. If this be so, what is the effect of such ghastly surroundings on our workers who are born and die there? As to its practicability, we have many proofs of this, and all that is wanted is some organisation on the part of those who welcome the scheme, and some liberal mindedness on the part of those whose property is now desolate and a stigma to our counties.

I see our President (Mr. Somers) is leaving the room to catch his

train. Perhaps before he goes he will give us some assurance of his help. I mean, would he be in favour of such a committee being formed?

Mr. SOMERS: Yes, certainly.

At this point of the proceedings, the chair was taken by the VICE-PRESIDENT (Mr. BROOKS).

Mr J. W. HALL: It is not very often that we have a subject of this sort brought before us; but I recollect that at one of the presidential addresses at the Institution of Civil Engineers, the President called attention to the fact that the quantity of timber in the world was becoming rapidly reduced in amount. It was being used up so rapidly that he feared there might be a difficulty within measurable distance of obtaining timber for piles and temporary works. How far this district may be expected to supply any demand for timber which may in the future be experienced, I have no possible means of knowing, but what little I have seen done in the way of planting on the pit banks has been only on a very small scale, and has not been very successful, though that is perhaps because we have not gone about it in the right way. I think the larger number of pit banks consist of a heavy bluish grey clay, which is really an inferior fire-clay, and this certainly does run together and crack. There are some shale tips, but these are generally set on fire by the ashes from the engines, and they are generally turned into material for making red foot-paths. When a boy, I thought this red material was gravel. It is used almost exclusively for path making in this district. There is no doubt that trees can be grown in the Black Country, as we see in our parks; but at the same time, there is a great deal of difficulty in getting them to grow, and I think half or two-thirds of them have had to be planted twice over, but perhaps that is because we do not understand how to do it.

Mr. WALTER JONES: I have read the paper through twice, and the more I read it the more interested I am in it. I was surprised to hear that there was so large an area as 14,000 acres of waste land in the Black Country. I presume this means taking together all the waste spots scattered about the district. Now, we all go to distant places in the summer time—to North Wales, or Scotland, or the Continent. Why? Because we want to see something beautiful. Surely, if we could see something beautiful at home it would be better than the present hideous nightmare which prevails in some localities. I, therefore, beg to second the resolution Mr. Tucker has proposed. Many years ago I noticed Marguerites growing in great profusion on some of the pit mounds of this district. If they only grow blackberry bushes, that would be better than nothing. Someone said there were no rabbits. It struck me that if you could introduce some rabbits, the colliers would not object to have an occasional day rabbitting. The question is, would

this scheme for tree planting pay? Perhaps not in dividends. But it certainly would pay in the moral and physical well being of the people. I am surprised that the local authorities permit these huge disfigurations of the district without calling upon those responsible for them to make something of them. It would be better if the owners had said, "If you will level that mound you can have it as a football pitch." Some municipal authorities pay the whole of their rates from the products of their timber forests. That is done in Norway, and I fancy I have read that some town in England raises considerable revenue in this manner; but I cannot remember the name of the place now. I should think some enterprising colliery proprietor would be willing to devote five per cent. of the income previously drawn from the land, in now trying to beautify it. Anything in the direction of the utilization of by-products is a step in the right direction, and surely making use of these waste pit mounds is something of that kind. Colliery proprietors and manufacturers have made their fortunes out of the land and then left it an unsightly wilderness; the least they can do is to be willing to try to do a little towards setting it in order again. As an example of what can be done to make unpromising localities beautiful, take Bournville, and see what the Cadburys have done there. That was a splendid idea. I hope a copy of this paper will be sent to most of the colliery proprietors and mine owners, or their agents.

Mr. John Fellows: I rise with great pleasure to support the resolution. The paper is extremely interesting and I think it is very practical. We know that timber can be grown on these pit mounds. At Corngreaves, some years ago, the southern slope of a pit mound was planted with Scotch fir and sycamore, and they have come on very well indeed. The chief difficulty is in obtaining suitable soil. Suppose it is a pit where they have had a good lot of slack. The slack most likely has been screened and the fine has been set fire to, so that only the ash remains. That is frequently the case. The only other available substance is material which has been drawn up the pits along with shale, and this, I think, would be suitable. But the chief part of waste material to be found on the ground in South Staffordshire is a sort of fire-clay with very little soil, and these mounds, as a matter of fact, in some cases are being made into bricks. It must be distinctly borne in mind that, to make this scheme a success, it requires a man who has had experience in forestry, and there is so little acreage in this country devoted to forestry that I think one of our difficulties would be to get men who could superintend the planting of the trees. These pit mounds are to be found all over the country in the coal and iron districts. They are unsightly masses. We have heard, and we believe it to be correct, that these mounds can be converted into beautiful copses of trees, and that these will also improve the surrounding land, and that the speculative builder will be anxious to secure that land for building private residences thereon, and that this will increase the rateable value of the

district. Such considerations, coupled with the knowledge that it would be for the good of the community to have these spots made beautiful, should be sufficient inducement to cause the local authorities to acquire these mounds and plant them. After planting them, they might make paths through them, so as to create public walks through these new woods. I should like to know if it is Mr. Stone's opinion that these trees will grow upon slopes of any aspect, and also whether it is his opinion that the tops as well as the sides of these mounds are suitable for the growing of timber. It would be a good thing if the matter could be taken in hand by a committee and properly pushed forward. If so, we shall before long see a great improvement in the aspect of this district.

Mr. Walter Jones: If the District Councils plant these trees and cut the roads through, will the present owners hand the property over for public use, instead of keeping it for their own profit? Of course, public authorities cannot be expected to beautify private property.

The Vice-President (Mr. Brooks) : Mr. Stone has dealt with his subject in a masterly manner, and we are indebted to him for bringing the matter forward. Undoubtedly, the success of any scheme for replanting the mounds of this district would depend largely upon such gentlemen as The Earl of Dudley, who owns enormous areas of such land. The Old Park, would make a splendid site for a start. If the committee could induce Lord Dudley to plant it, it would be a good thing, and I think the experiment would be successful. We have trees flourishing at present in various parts of the Black Country. Indeed, wherever trees and parks have been planted in this district on old pit mound land, we find they have done exceedingly well.

Mr. Stone : It is strange that the report of the Woods and Forests Commissioners should have been published only a few days before the reading of my paper. I have not yet been able to get a complete copy of the report, but according to the summary which appeared in the *Birmingham Daily Post*, it would appear that the Commissioners entirely ignore the Black Country. I think that is too bad. Much to my surprise, the deliberations of the Committee were concluded without any reference whatever to the Black Country. But it may not be too late, for their report is simply a matter of recommendation, and it lies with Parliament to see those recommendations carried out. It is not even now too late to ask two or three sympathetic Members of Parliament to do something for us, so that if Parliament acts upon the Commissioners' recommendations, it may also add a rider to the effect that the Black Country shall not be forgotten. I believe that Mr Howard stayed also with Sir Henry Fowler, and that the latter was very much interested. If we could get Sir H. Fowler's assistance, we might also obtain the help of other Members of Parliament. A word or two from the local Members of Parliament might stimulate the local

authorities to take some steps. But the best thing for us, as practical men, is to do what we can ourselves. Let us not forget to begin at the beginning by ourselves doing what we can at the bottom, even if we cannot move those at the top as fast as we should wish. I should like to point out that Professor Schlich, in an address before the Society of Arts, said there were 2,000,000 cubic feet more timber being used up annually in Europe than was being replaced by growth. Now that is a very serious matter, for as the supply shrinks you will have to pay higher prices. That is happening all the time. The price of timber continues to go up owing to increasing scarcity; you never hear of it coming down. In Canada, Norway, Sweden, Russia, Finland, and other places where forests abound, and where there are enormous supplies of timber, it is the habit of the people to cut down first the supplies which are nearest to the rivers, in order to be able to float the timber away. Under those circumstances the cost of transport is not very great. But as they have to go further and further inland they have to pay haulage expenses, and then, of course, there comes a point where it does not pay to bring it to market. Therefore, during the next 20 years you will have to pay some very big prices indeed for pit props, and that should be an argument in favour of growing your own. For in 20 years' time you could have a good supply of your own. I can assure you that trees will grow just as well in heavy clays as they will in any other soil, for I know clays in Gloucestershire, which are exceedingly heavy, and yet trees grow well there. Whatever the soil may be does not alter the force of the argument, because they will grow just as well in heavy clays as in other soils. Mr. Jones referred to the practice of municipalities in Norway drawing an income from the woods. Well, in Norway the whole of the population practically draws its income from the woods, as well as the municipality. It is a very pretty custom there to plant 1,000 trees at the birth of each child, and in 21 years this new forest is handed over to the child as a nest egg. That custom might be adopted in this country. I believe there is a considerable amount of potash and soda in coal ash, and certainly wood ash is one of the best things you can put on a garden. Though the coal ash may be a long way behind wood ash as a fertiliser, yet there are constituents of value even in that. It is not necessary to have trained foresters to carry out such a scheme. Ordinary people without special training would do if they had proper instructions. Simple labourers can do it, if they are told how. The mistake generally made is that saplings are put in when too old. People generally start by putting in trees about three feet high, often sacrificing most of the rootlets; this means that you then have a root-system too small to replace the water which the upper portion of the tree gives off.

The Vice-President: I have very great pleasure in proposing a vote of thanks to Mr. Stone. Apart from the question of profits, there would be a great improvement upon the present state of affairs, aes-

thetically, if his ideas could be carried out, whether there were any pit props or not.

Mr. JOHN KEELING seconded the resolution, which was carried unanimously.

After some conversation it was decided that the subject of Mr. Tucker's proposition should be referred to the Council.

CORRESPONDENCE.

PROFESSOR R. A. S. REDMAYNE (Birmingham University) : I have been much interested in reading Mr. Stone's admirable paper on "The Utilization of Pit Tips for the Growing of Pit Timber," and would like to say how thoroughly in accord I am with the object he has in view, viz., the re-afforesting of the waste lands of the Black Country.

Whilst well aware that some pit heaps are suited for the growing of trees, I am in some doubt as to whether *all* pit heaps could be so utilized, even of those which are not subject to spontaneous combustion, for the reason that they vary, even in the same district, both in respect to the chemical constitution and the mechanical structure of the material of which they are composed. This difference being accounted for by the fact that the *débris* has been derived from different rock beds, such as sandstones, shales of various kinds, fire-clays, and inferior coal.

A pit heap may be mostly built up of sandstone, and at the same time be partly or entirely covered with, say waste coal or other rubbish, or it may again be entirely or partially composed of burnt-out *débris*. In Northumberland, Durham, and South Wales, districts with which I am best acquainted, the pit heaps are of this varied character. I note, however, that Mr. Stone says of the Midland pit heaps, that "They consist chiefly of shale in different stages of decomposition."

Some abandoned pit heaps are soon covered over with a growth of grass or weeds; others not so soon or at all, which is due, in a large measure, to the difference in weathering properties of the *débris* of which they are formed. It is apparent, however, that trees will often flourish where grass will not. That trees will grow, and grow well on some pit heaps, Mr. Stone has abundantly proved; and I would add two further instances to those already quoted by him. In each of these the old pit heaps are densely wooded with fine plantations of Scots firs and larch. Both of these are in the county of Durham—one at Sheriff Hill, the other close to Low Fell Railway Station on the N.E. Railway Co.'s main

line North. Were it deemed of sufficient interest, I could procure photographs of these plantations, which are of a decidedly picturesque appearance.

Hilly ground, with a favourable aspect—south and south-eastern slopes—is best suited for forest vegetation, as it receives and retains most moisture, and there is this further advantage in hilly ground—better drainage is secured—often an important factor in determining the growth of trees. This last desideratum would be ensured by the trees being planted on pit heaps.

The physical properties of the soil are of greater importance than its composition, and deep hygroscopic soil, moderately fertile, is preferable to rich shallow soil.

It may be mentioned that statistics show that more than nine-tenths of the timber used in the world is derived from Coniforœ, but quite apart from this fact, which has not, perhaps, any bearing on the question under consideration, I am inclined to agree with Mr. Stone, and Mr. Baylis as to Scots firs and larch (and birch also) being the most suitable trees with which to plant the pit heaps, but am not so convinced with respect to the sycamore. Would the latter flourish as well as the others on this kind of ground?

Would not it be both interesting and desirable to experiment also with some trees other than those indigenous to this country. We know that the copper beech, the horsechestnut, and some other trees were originally imported from the Continent, and it is quite possible that the nature of the ground we are considering may prove peculiarly suited to some of the trees flourishing in the higher altitudes of say Natal, Northern India, Australia, and New Zealand. It would be as well at any rate to hear the views of authorities on forestry on this point.

The question is practically one of improvement of the scenery, and hence enhancement of value of neighbouring land for residential building purposes, for the actual money return from the timber would be small, if any, during the life time of those who planted the trees; but the aspect of the whole district would be greatly beautified.

As to the utilization of slag heaps—slag has, and had, a marketable value for the purpose of the manufacture of slag cement. In 1886, the Georgs-Marien-Bergwerks-und-Hütten-Verein, after having manufactured, by way of experiment, some 30,000 tons, resolved to increase the capacity of their plant to 300,000 tons a year. It would be interesting to learn what success has attended this industry. There was, some years ago, a company called the "Improved Cement Company," with offices in Mark Lane, London, which, if still to the fore, might afford

information on the subject. Artificial blocks composed of furnace slag, coke cinder, and cement were used in the construction of the Charlottenburg Bridge. The blocks weighed from 18 to 20lb. each, and were made in Upper Silesia. It was expected that they would be more durable than natural stone. There are doubtless other purposes to which furnace slag might be put.

The Fifth Meeting of the Session was held at The Institute, Dudley, on Saturday, the 7th March, 1903.

In the absence of the President, THE VICE-PRESIDENT (Mr. W. BROOKS) presided.

The minutes of the previous meeting were read, adopted, and signed.

Messrs. Walter Macfarlane, J. H. G. Davis, John Ellis, W. K. Broughton, Albert Screen, and Ernest A. Screen were elected members of the Institute.

Mr. JNO. W. HALL, A.M.I.C.E. (Past President), then read the following paper :—

ON GAS AND SOME OTHER HEAT ENGINES.

By JOHN W. HALL, A.M.I.C.E.

Eight years ago the writer had the honour of reading before this Institute a paper dealing with the cost of producing power by means of the steam engine, then the only prime mover requiring serious consideration by managers of large works. Since then other forms of heat engines, more particularly gas engines, have been so much improved, that it is necessary for any one having to consider the production of power to acquaint himself with the capabilities of such engines.

Thermo-dynamics, the science which treats of the conversion of heat into work, is usually expressed in such an abstruse mathematical form as to deter many people from studying the subject at all, and it may, therefore, be as well to begin this paper by giving in the simplest possible language, the elementary facts upon which the action of all heat engines depends, and what consequently are the limits of their possibilities: afterwards to refer to some of the best known varieties which now are, or have been formerly in use, concluding with certain recent developments, indicating the probable line of future advances.

Heat engines are contrivances for converting into work the sources of heat obtainable in nature. Work is effort overcoming resistance, and it is measured in terms of the weight which the work would be capable of raising in a given time, through a definite distance, against the action of gravity. For practical purposes, the engineer measures work by the number of pounds raised through a definite number of feet in one minute, and the raising of 33,000 pounds one foot high, or the exertion in one minute of 33,000 foot-pounds, he agrees to term "one-horse power," although this is actually about 50 per cent. more work than a good strong horse can accomplish.

As to the exact nature of heat, there have at different times been various conflicting theories, but it will be sufficient for our present purpose if we simply define heat as being that property of matter which is capable of being converted into work by suitable means.

Heat and work bear a certain definite relation to each other. The expenditure of so much heat as is sufficient to raise one pound of water when at its maximum density through one degree Fahrenheit would be sufficient, if there were no loss in conversion, to raise a weight of one pound through a distance of 772 feet per minute, and conversely exerting upon water when at its maximum density a force of 772 foot-pounds, will raise one pound of it through one degree Fahr. This relation,

commonly called "Joule's equivalent," is represented in all books on Thermo-dynamics by the symbol J.

All engines receive the heat at a higher level of temperature and convert into work so much of it as from the nature of their construction they are able to usefully employ, and the remainder, the larger proportion, which they are unable to use, they must pass to waste or, in the language of the text books, "reject" at a lower level of temperature.

As the operation of all heat engines of every description, whether steam engines, air engines, gas engines, or oil engines, is based on the same property of matter, all may be compared on the same basis, and referred to the same standard.

The vehicle for receiving the heat is in most cases a gas, in some cases a fluid, which before use is converted into vapour, an unstable form of gas, but it may even be a solid. For instance, two or three centuries ago walls which had been thrust outwards by the weight of a roof were pulled back into position by iron bars passing through both walls and provided at their outer ends with suitable cotters, by means of which the spread of the wall could be resisted. On every alternate rod were hung a row of lighted lamps; the heat expanded the iron rods, and the cotters were then tightened. The lamps were next removed to the other set of rods, which were similarly heated, and when these had expanded the cotters in them were driven home. When the lamps were removed these rods contracted, dragging the walls inwards; the first set of rods were then again heated, and their cotters driven tight, each alternate set being so treated until the walls were brought back again to their correct position.

In this case we have an actual performance of work by heat, making use of the linear expansion of a solid material, namely iron, as the substance for converting the heat into work. A powerful engine could be constructed on this system, a rod as it expanded or contracted driving a toothed wheel by means of a rachet against a resistance, but the arrangement would be inconvenient and very slow, while it would be possible to usefully employ the expansion of the material in only one direction, namely, its length, the increase in the thickness and width of the rod serving no useful purpose whatever. Hence in practice vapours or gases are always used as the vehicle for converting the heat into work, because in the first place their increase in volume, that is in all directions, can be utilised; and, secondly, because their change of volume is both very rapid and considerable in extent, which more than compensates us for the reduced intensity of pressure exerted.

The gas or vapour employed flows through the engine, and hence is termed "the working fluid" (the word fluid not referring, for instance, to the water in the boiler, but to the steam formed from it), and the efficiency of the engine as a heat engine, theoretically, is independent of

the particular fluid chosen, but depends entirely upon its temperature, though there are practical reasons, as we shall see, for employing certain fluids in preference to others.

All perfect gases expand by exactly the same amount for each degree they rise in temperature, and contract by the like amount for each degree they fall in temperature, this change of volume amounting to one part in every 493 parts of the volume which the gas has, when at the temperature at which water freezes, namely, 32°F. On diagram No. 1 is a vertical line A B, on which are marked, at their correct distances apart, various temperatures according to the Fahrenheit scale. At the point representing 32°F. a line C D is set off horizontally, whose length represents to a convenient scale the volume of any gas at 32°F., while above are set off, to the same scale, the volume which the same gas would have at the various temperatures marked; the length of the line representing the volume of the gas at every temperature is increased beyond the length of the line C D by so many 493rd parts of the length of C D as the gas has risen in temperature above 32°F. As the increase in the length of the lines is exactly proportionate to the increase in volume, the line E D joining all these points is evidently a straight line, and as the same rule holds good below 32°F., the distance measured from the vertical line A B to the inclined line A E gives exactly the volume of the gas at the corresponding temperature on the Fahrenheit scale.

Seeing that gases decrease uniformly in this manner by 1/493rd part of the volume which they have at 32°F., it would appear that when the gas has fallen through 493°F. it will have lost all its heat, and possess no volume whatever. This point, which is 493° lower than 32°F., or —461°F., is called "Absolute Zero."

In 1824 Sadi Carnot, a young French Captain of Artillery, pointed out that we may compare this point of absolute zero, below which the gas cannot fall in temperature, to that of the sea level beyond which water cannot fall in space. Water in falling from any given distance above the sea is capable of performing work equal in amount to its energy of position, that is the energy which would have to be expended in lifting it from the sea level to the level it then occupies, which energy it will therefore give out again when it falls. Thus 33,000 lbs. of water at a height of one foot above the sea would be cabable of exerting by its fall a force of 33,000 foot-pounds, which occurring in one minute would develop one horse power.

Diagram Fig. 2 shows a lake at the level A raised a certain distance above the sea level B. The total power which any given weight of that water could generate by its fall is represented by the distance A B, supposing the water wheel shown on the diagram had a diameter of A B. But as the water wheel has only the diameter A C, it can only utilise the power exerted by the water in its fall from A to C, the power exerted

in the fall from C to B being entirely wasted, because the water falls freely outside the wheel without performing work. This state of affairs is exactly analagous to the utilisation of heat by a heat engine, the position B beyond which the water cannot fall answering to the absolute zero beyond which the temperature cannot fall, and the level at which the water stands in the lake representing the level of temperature to which the working fluid supplied to the engine has been raised at the moment when the supply to the engine commences.

Our water possesses weight and has been raised to a high level marked A, and our ability to get work from the weight is dependent on our allowing the heavy fluid to fall *while contained in our water wheel,* which is an engine for converting weight into power, from the high level A to a lower level B, and if there is to be a continuance of work there must be a continuous flow of the working fluid through the engine falling from a higher to a lower level. Similarly the steam or gas supplied to a heat engine has been raised to a high heat level; our ability to get work from the heat is dependent on our allowing the heated fluid to fall while contained in our engine, which is a contrivance for converting heat into power, from the high level from which it has been raised down to a lower level; and similarly, if there is to be a continuance of the work there must be a continuous flow of the working fluid through the engine from a higher to a lower level of temperature.

The possibility of using the whole of the energy contained in the water depends on our ability to allow the water to fall from the highest point attained to the lowest point to which it can possibly fall, namely, B, which is sea level, and therefore the absolute zero of position. Similarly our ability to use the whole of the heat contained in our "working fluid" gas, or steam, or air, is dependent on our ability to allow our temperature to fall to the lowest possible level of temperature, that is to the absolute zero of temperature.

But as most water wheels are situated at a distance from the sea, and much above its level, it is not practicable to reject the water at sea level, and it must therefore be discharged into the lowest receptacle in the neighbourhood, namely, the nearest stream, which we may call the level C. In that case only the power obtainable by the fall from A to C can be utilised, while that from C to B is not, in that place, practically available. So with our heat engine, as we are not situated in the neighbourhood of absolute zero, but considerably above it, we cannot reject our heat at the level of absolue zero, but must discharge it into the receptacle having the lowest level of heat to which we can obtain access, which in our case is the temperature of the atmosphere in which we live, and may be put at an average of 50°F. In this case, if we also take the level of temperature at which our engines receive heat as A, and the level of temperature of the atmosphere at which we are compelled to reject it as C, while B below it is absolue zero, obviously we can only

use that portion of the heat from A to C, and are as incapable of using that from C to B as the miller whose mill is situated in an inland mountainous district, and who must therefore discharge his water into a stream in the hills. If he is to utilise all the potential power of his water he must sink his tail race to sea level, and if we are to utilise all the potential power of our heat we must sink the chamber into which our engine discharges down to a temperature of absolute zero.

It is usual when dealing with heat engines to express the higher temperature in degrees absolute at which the engine receives heat by the Greek letter T^1 (Taw), and the level at which the engine rejects the heat by T^2, which two distances are so marked on the diagram. Now if the total distance through which the heat might have been lowered is the distance A B, or T^1, while that through which it is actually worked is only the distance B $C = T^1 - T^2$, leaving the distance C B unused, it is clear that the efficiency of the water wheel or of the engine cannot possibly exceed the ratio $\frac{T^1 - T^2}{T^1}$, the equation used to express the fact in every book on Thermo-dynamics. In this case all the figures are expressed in *absolute temperatures.* If the usual temperatures are employed the equation must be written—

$\left.\frac{T^1 - T^2}{T^1 + 461}\right\}$ if the temperatures are given in degrees Fahrenheit, and

$\left.\frac{T^1 - T^2}{T^1 + 274}\right\}$ if the temperatures are given in degrees Centigrade.

The late Sir William Anderson, in his excellent book on "The Conversion of Heat into Work," expresses the fact very clearly, thus:—

"The quantity of heat or energy given out by a gas as it cools is in direct proportion to the change of temperature (that is absolute temperature). It is obvious that the only way to get all the energy out of the gas is to cool it down to absolute zero, and, therefore, if you only cool it to one-sixth of the way to zero, you can only get one-sixth of the possible work."

Owing to leakage and the spilling of water on the way, which must be allowed to begin its escape from the buckets before they are at their lowest point, or it would be carried up on the rising side of the wheel causing a resistance, a wheel of this type, though well designed and constructed, cannot utilise more than 80 per cent. of the available power due to the fall of the water; similarly the most perfect heat engine we can make will inevitably waste a certain portion of that heat which it could conceivably employ owing to leaking pistons and valves and the spilling of heat due to conduction. The heat engine is physically worse off than the water wheel, because heat can escape by conduction and radiation through the solid walls of pipes and cylinders, but water cannot flow through the solid sides of the buckets of the wheel; in fact,

our heat engine is much like a wheel whose buckets are porous. In both water wheel and engine there is a further loss, due to the friction of the moving parts, which still more reduces the efficiency. Moreover, whatever be the higher and lower level of the water, it will be obvious to every one that to obtain the maximum efficiency between those limits the water must be supplied at the highest point of the wheel, and not allowed to escape until it has reached the lowest point. Similarly in a heat engine, to obtain the maximum efficiency within the limits of temperature between which it works the whole of the heat supplied to the engine must be supplied at the higher level, and it must all be rejected at the lower level, an important point which has not always received the attention which it deserves.

The value of Carnot's theory is that it defines clearly the limits attainable under ideal conditions, so indicating the nature and direction of possible improvements. Failure to appreciate that such inevitable limits to efficiency do exist, and the reason for them, has caused the fruitless expenditure of a vast amount of time and money in attempts to attain what a knowledge of Carnot's theorem would have shown to be inherently impossible.

Of all the types of engines the air engine is from the theoretical point of view the simplest, because the working fluid, air, is present everywhere, and therefore does not require to be specially formed for the use of the engine. Moreover, the only change that the air undergoes in its passage through the engine is a change in volume and pressure, but no change in form or chemical constitution. The next most simple engine, theoretically, is the gas engine fed with gas, because there is no change in form but only a chemical change due to the combustion of the gas, the gas and air both entering the engine in a gaseous form, and being discharged in a gaseous form as products of combustion, though in the process of manufacturing the gas a solid is converted into a gas. In most oil engines there is a change in form from a liquid to a vapour, either in the engine itself or in some vessel external to it, and then a chemical change, the products of combustion leaving the engine in a gaseous state. In the steam engine, although to the ordinary mechanic the simplest of the four types of engines, the changes are really of a more complex nature. In the first place, the fuel burnt under the boiler is changed in the process of combustion from a solid to gas, then mixed with another gas, namely, the air, and finally discharged from the chimney as gas, while the water which enters the boiler as a liquid has its state changed from a liquid to a vapour, which is an imperfect form of gas, and of this vapour part is brought back again to the liquid condition in its passage through the engine, and part is rejected as vapour. As no change of state or transfer of heat from one body to another can in practice be effected without some loss in conversion or transmission, it is not surprising that the steam engine is not a very efficient heat engine.

So much for theory; now for practice.

To be successful, a heat engine must comply with the following conditions:—

(1) It must convert into work a reasonable proportion of the heat supplied to it, and of the gross power thus developed too much must not be wasted in internal resistance, or friction of the mechanism; otherwise the nett power available for performing work will be unsatisfactory.

(2) It must be capable of employing a fuel which is not too costly in the neighbourhood where it is to be set to work, or it will pay to use a less efficient engine capable of working with cheaper fuel, if the fuel bill be thereby reduced.

(3) It must have a reasonably long life, and must not be too costly to maintain in fair working order.

(4) It must not require more than ordinary skilled attendance.

(5) Its first cost must not be excessive.

(6) It must not occupy too much space.

(7) It must not create a nuisance, nor be unduly dangerous to person or property.

The most useful heat engine is that which best complies with these conditions, their relative importance being indicated by the order in which they are enumerated above.

STEAM ENGINES.

Water wheels and wind mills are really heat engines, seeing that it is the heat of the sun which raises the water to the clouds, and causes the motion of the air we call wind; but the first useful heat engine driven by heat applied directly by man was a crude form of steam engine, called originally "a fire engine," a name more appropriate than its inventors realised, seeing the steam was merely a convenient vehicle for the heat, which really did the work. Its priority of conception is attributable to the fact that the effects of heat on water and watery vapour were more obvious to the senses than its effect on other substances, such, for instance, as air, which remain fixed gases at moderate pressures and temperatures, while its practical realisation is due to the fact that water exists as a fluid at atmospheric temperature, is changed to the gaseous form by a very moderate rise in temperature, and is readily converted back to a fluid at pressures below that of the atmosphere, and therefore very moderate temperatures and pressures could be employed in engines actuated by it. It was practically impossible to construct what we should now call an engine to be worked by any gases at pressures higher than that of the atmosphere, much less at the pressures to which we are now accustomed, before the close of the eighteenth century, for no appliances then existed capable of boring a cylinder. To prevent the air finding its way past the piston which fitted roughly

an unbored cylinder, a layer of water was maintained on the upper surface of the piston of Newcomen's engine. Water at atmospheric pressure flows through an opening into a vacuum with a velocity only $\frac{1}{290}$th that of air, and $\frac{1}{360}$th that of steam; owing to this, comparatively little leakage occurred past the piston, provided the pressure of steam beneath it was not more than that of the atmosphere, because the air could not leak downwards without driving before it a heavy fluid, which therefore flowed slowly. If, however, the pressure below the piston had been greater than that above, the water would have been blown back, and the steam would have flowed past with great rapidity. The water, in fact, formed a species of packing, which is still found sufficiently tight for the air pump bucket of a modern engine.

Savery's, the first practical steam engine, did not make use of a piston and cylinder, the steam pressing directly on two columns of water alternately. which were forced up by steam thrust out of the boiler by the heat applied below it, the volume of the steam being practically the same thing as a plunger driven forward by any other power. The pulsometer of to-day is a very similar contrivance, only fitted with automatically operated valves for distributing the steam alternately to the two vessels. What was the efficiency of this engine is not known, but it proved to be as costly to work as were horses. The limits of its powers was soon reached, and one erected near Wednesbury failed to unwater the mine, although the pressure was raised until the boiler or some important part of the plant exploded.

Newcomen employed a cylinder in which worked a piston, whose weight was more than balanced by that of the pump rods slung from the opposite end of the working beam, whereby he could use steam at a pressure actually less than that of the atmosphere, thus avoiding any danger of explosion. The water in the boiler expanded into steam by heat was, with the assistance of the counter-weight, enabled to force up the piston against the pressure of the atmosphere. The communication with the boiler was then closed, heat was extracted from the imprisoned steam by throwing cold water on the sides of the cylinder, causing the steam to shrink in volume, so that the pressure of the atmosphere could drive down the piston against the reduced pressure of the steam, and in so doing lift the pump rods. By an accident to his first engine at Wolverhampton in 1713, Newcomen discovered that by injecting water into the cylinder heat could be more rapidly extracted from the steam, and the speed of the engine much increased. Newcomen's engine really worked by forcing back the atmosphere, the action being precisely analogous to the lifting of a weight nearly equal to the pressure of the atmosphere multiplied by the area of the piston, and permitting this weight by its fall to raise the water.

Owing to the loss of heat occasioned by the water packing of the piston, and the admission of cooling water within the cylinder, which

losses had to be made up by heat from the boiler, Newcomen's engine consumed 240lbs. of coal for every horse power developed.

With the idea of avoiding the waste of heat due to the alternate heating and cooling of the working cylinder, Watt in 1765 conceived the idea of cooling the steam in a distinct vessel, the cylinder thus being placed between the boiler where the heat was supplied for expanding the steam, and the condenser where the heat could be extracted to reduce or "condense" its volume. Boulton, who found the flow of water at Soho Pool insufficient to work his water wheel during dry seasons, was looking out for some means of pumping the water and using it over again, when he made the acquaintance of Watt, and thus in 1774 commenced that partnership between the two men which, by enabling Watt to perfect his plans, was to make their names famous all over the world. By the adoption of the separate condenser, the use of bored cylinders and properly fitting pistons, and the raising of the upper limit of temperature until the pressure was increased to 15lbs. per square inch above the atmosphere, as much as he considered safe, having regard to the boilermaker's art at the time, and the adoption of other refinements, Watt reduced the consumption to 50lbs. of coal per horse power per hour. With the better methods of construction available to-day there is no appreciable difficulty in dealing with steam at a pressure of 150lbs. per square inch, and many engines are working at pressures of 200lbs. and over. With such pressures, triple expansion engines are now constructed which will work with 1¼lbs. of good Welsh steam coal per I.H.P.

A pressure of 200lbs. per square inch above the atmosphere answers to an upper limit of 338°F., and if the engine is not fitted with a condenser there is available as the lower limit of rejection a temperature of 212°F., at which water boils at atmospheric pressure, or, if a condenser is provided, a temperature of 50°F., the usual temperature of the cooling water. To get the temperature of the condenser down to this point would require so much water, the removal of which against the pressure of the atnosphere would absorb so much power, that in practice it is not advisable to go below a temperature of 110°F.

Naturally you will ask if the efficiency of a heat engine depends simply upon the highest and lowest temperatures between which the engine works, how is it that the compound engine is more efficient than a simple engine? Now we have seen that the efficiency of a water wheel would be impaired if the water were not all supplied at the highest level, and rejected at the lowest. Suppose that owing to some inherent property of the only materials from which a water wheel could be constructed, the water, though supplied at the top of the wheel, ran rapidly through the first few buckets which could not be kept full, so reducing the effective head of water, which yet clung so tenaciously to the buckets at the bottom that the wheel had actually to raise the water some way

up the back of the wheel before it fell clear. It is clear that in that case there would be a serious falling off in efficiency. Suppose that these tendencies to fall away at the top and hang on at the bottom increased with every increase in the total fall, there would evidently come a point where it would pay to split the fall up into two parts, the second wheel taking the waste water from the first, as shown in Fig. 3, and this in spite of the fact there would be the friction of an additional shaft. Further, there would come a point where it would be advisable to adopt a third stage, a fourth, or even more, the number depending upon the height of fall, and we can readily see that the cost of the two or three small wheels might even be less than that of one large one.

Now owing to the fact that the cylinders of our engines must be constructed of a metal which causes a sudden drop in temperature immediately we admit the fluid at a high heat level, which temperature adheres to the metal for an appreciable time after the communication with the lower level of heat is opened, and that this tendency increases more rapidly than the height of the drop, we find it adds to the efficiency and reduces the cost of our steam engine to divide the drop into two or more stages, increasing in number as the height of the drop increases, so that the superior efficiency of a compound or triple engine is not a contradiction of Carnot, but a perfectly scientific adaptation of methods to suit the use of the only materials we have available from which to construct our engine. Had we any material not greedy for, or retentive of, heat from which we could construct a cylinder, the compound engine would prove less efficient than the simple engine at every pressure. Under existing conditions there is considerable loss by the transfer of heat from the working fluid when at its hottest to the metal of the cylinder, which in turn gives back part of this heat to the working fluid when at its coldest point, much as if water leaked from the upper buckets of a water wheel and fell direct into those at the back which were rising.

Now just as there may be several water wheels one below the other driven by the same falling stream of water, similarly there may be several engines one below the other driven by the same falling stream of heat; nor is it essential that the vehicle for conveying the heat should be the same at each step, for it is the heat only and not the fluid which is utilised. Thus the exhaust steam has been utilised to raise the temperature of ether vapour.

The engine of the steamer "Bresil,', starting with an initial pressure of 43lbs. per square inch above the atmosphere, corresponding to a temperature of 290° F., exhausted its steam at a pressure of 7½lbs., corresponding to a temperature of 234° F., the exhaust steam being used to heat ether in a second engine. About two-thirds of the work was done by the steam, and one-third by the ether.

Similar experiments are now being made in Germany with the object of using ammonia vapour or sulphur di-oxide gas, which latter, at a

temperature of 140° F., has a pressure of 156lbs. per square inch, and at 60° F., a pressure of 41lbs. per square inch. By this means, it is said, 34·2 per cent. of additional power has been obtained from triple expansion engines, and their consumption lowered from 11·2lbs. of coal per horse power to 8·36lbs.; while a compound engine using 18·35lbs. of water evaporated into steam, gave an increased power of 41·7 per cent. when the heat contained in the exhaust steam was employed in heating this gas. There are, however, very considerable difficulties in preventing leakage of such vapours, while sulphur di-oxide, though serving as a lubricant for the engine, is liable to take up water vapour, and form sulphuric acid, which certainly is not an efficient lubricant.

The only possible utility in employing such working fluids in a second engine, instead of passing the steam into an ordinary condenser, is the lowering of the point at which the heat is rejected to the level of 50° F, instead of to 110° F. No other benefit can arise unless the communication of heat to the cylinder by such vapours at the moment of its admission, when the metal is colder than the working fluid, and the extraction of heat from the metal at the time of rejection of the fluid, when the latter is colder, is less than with steam; but to allow for the unavoidable loss in transfer of heat from the steam to the secondary vapour, and the friction of the second engine, the saving in this respect must be much greater than seems at all probable.

A method much more likely to yield satisfactory results, seeing we cannot reduce the temperature of rejection, is to raise the temperature of supply. But to increase the upper temperature of the steam by evaporating it from water at high temperature, involves dealing with pressures altogether out of proportion to the increased temperature as shown on the diagram Fig. 4. If, however, we heat the steam when it is not in contact with the water, we can raise its temperature without raising its pressure, this process being known as superheating. The chief restriction in this direction, is that at high temperatures, the oil employed in lubricating the cylinder and piston splits up into its chemical elements, or undergoes some other change which destroys its lubricating properties, so that the working parts are rapidly cut to pieces, while special valves must be employed, or there is great trouble with leakage. This consideration limits the higher level of temperature to 600° or 700° Fahr.

In his paper on the Steam Engine in 1894, the writer ventured to predict that within ten years we might expect to have engines at sea with four or five cylinders using pressures of 250lbs., and that as tubular superheaters were then being made, superheating would once more receive attention. In *Engineering* for January, 1901, appeared drawings of the 1,625 I.H.P. five-cylinder engines of the "Inchdune" and "Inchmarlo," built by the Central Marine Engine Company, of

Hartlepool, driven by boilers blowing off at 267lbs. per square inch, fitted with tubular superheaters, which raised the temperature of the steam to 460°—480° F. These engines, on an extended trial run from Hartlepool to Dover, burned 0·97lbs. of coal per I.H.P, per hour, giving the almost incredible result of transporting one ton one nautical mile for one-third of an ounce of coal.

The steam engine when small and in bad condition, such an engine as is used in the small factories of this country, will consume about ten pounds of slack per I.H.P., but a reasonably good one need not take more than five pounds. A compound engine, of say 300 H.P., of good construction, can be made to work with about three pounds of slack; a larger engine of 1,000 H.P. about two pounds of slack, while the best results with the most efficient engines of large size, working with superheated steam under the best conditions, is a fraction under one pound of Welsh coal, or say one and a third pounds of local slack per H.P. Taking the cost of slack at 7s. 6d. per ton, equal in round figures to one-25th of a penny per pound the cost for fuel per horse power, works out at ten-25, five-25, three-25, two-25, and say one-20th of a penny in the five cases just given. The last two of these results are undoubtedly light, and unless fuel is very dear, it simply costs more in repairs and capital charges to obtain such results than the saving of fuel will pay for.

AIR ENGINES.

Engines employing air as the working fluid, called air engines, have been fairly successful from the heat efficiency point of view, but have ceased to be used owing to practical difficulties of construction. The first practicable machine was patented by the Rev. Dr. Stirling, in 1816, and was subsequently improved by his brother. One of 40 H.P. drove a factory at Dundee for many years with an expenditure of only $2\frac{1}{2}$lbs. of fuel per H P. per hour. The upper and lower temperatures are reported to have been 650° F. and 150° F. respectively, so that the maximum possible efficiency for the engine would be

$$\frac{650-150}{650+461} = 0{\cdot}45 \text{ or } 45\ \%$$

The least number of B.T.U. which would suffice theoretically per I.H.P. per minute are—

$\frac{33,000}{772} = 42{\cdot}7$. If the coal contained 12,000 B.T.U. per lb., the units supplied per minute by the fuel would be $\frac{2{\cdot}5 \times 12,000}{60} = 500$

so that the actual efficiency of the engine was only $\frac{42{\cdot}7}{500} = {\cdot}085$ or $8\frac{1}{2}$ per cent., or less than one-fifth of the possible result.

A variety of other types have since appeared, and though theoretically very simple, all air engines present considerable difficulties in practical use. If the air is heated by the combustion of fuel outside a vessel containing the air, as in the case of Stirling's, Ericsson's, or Rider's engines, the plate through which the heat has to be transmitted is rapidly destroyed by the heat, in fact, we may look on the water in the boiler of the steam engine as a convenient means of preserving from destruction the plate through which the heat is transmitted. If the combustion of the fuel occurs in a closed vessel connected with the cylinder, as in the Cayley and Buckett engines, the products of combustion passing through carry with them portions of the ash of the fuel, which rapidly destroy the working parts. Moreover, the specific heat of air, that is, its capacity for containing heat, is much lower than that of steam, with the result that an air engine, unless worked at very high pressures, must have cylinders immensely larger than a steam engine of the same power, causing the engines to be very bulky and costly. The air engines of the paddle vessel (we cannot say paddle "steamer") "Ericsson," of 360 h.p., had four cylinders, each of no less than 14 feet diameter, while the one horse power Ryder engine, still made by Messrs. Hayward, Tyler, and Co., for pumping at country houses, for which it is admirably suited, has a cylinder ten inches diameter by thirteen inches stroke.

Sir Wm. Siemens would appear to have recognised this objection to air, for in 1847 he patented a form of steam engine which was practically an air engine, generally similar to Dr. Stirling's, but in which steam was used instead of air, the steam being alternately heated and cooled. He carried out a long series of experiments with it at Smethwick in Messrs Fox, Henderson, and Co.'s (now the Patent Nut and Bolt Co.'s) works, but though some of the engines would appear to have been fairly economical in fuel, the practical difficulties of lubrication and of maintenance of joints at such high temperatures as he employed, caused their use to be discontinued. The engine is chiefly noticeable because the regenerator used with it was the germ from which originated the regenerator which produced the Siemens furnace.

There is a third type of engine in which the combustion of the solid fuel occurs within the actual working cylinder. A gun is a heat engine having an intermittent action and working at the high pressure of fifteen tons on the square inch; but in the Maxim gun we have a gunpowder (or rather cordite) engine working continuously, so long as the supply of the requisite fuel is maintained, and in the early form the gun was actually provided with a connecting rod, crank, and flywheel, though the latter oscillated instead of making a complete revolution. It is remarkable that the Abbé Dehauteville proposed an engine to be driven by gunpowder, and Papin even thought that this power was one more easily controlled than that of steam. An engine can be constructed to work

with any combustible material if in such a fine state of division that it will fire suddenly enough to provide the products of combustion with the requisite rapidity. Krupp experimented at Essen for some time with an engine, using powdered coal dust fed into the cylinder and fired there, but abandoned the experiments because of the wear of the piston and cylinder, and Mr. McCallum, formerly with Messrs. Tangye's, and at one time a member of this Institute, is occupied in attempts to render this engine successful by delivering water at high pressure into the space between the piston and cylinder, in order to wash away the ash from the working surface of the cylinder in advance of the piston. Some of you may have seen the engine in the Glasgow Exhibition.

OIL ENGINES.

For utilising the greatest number of thermal units contained in the fuel supplied to them, no engines yet made can compete with the oil engines, which have the further advantage of requiring no boiler or gas-making apparatus to require attention or occupy space, so that their first cost is moderate. They are convenient appliances, can be constructed in small sizes, and used where lighting gas is not obtainable. They can be started and stopped in a few minutes, so that no time is lost in getting up steam, which is important in the case of engines which are only required occasionally. An ordinary labourer can look after them with the occasional assistance of a skilled man to adjust the valves; the engine must have the valves removed and cleaned, which is easily done and occupies only a few minutes, once every two or three days. In most oil engines the oil is first converted into vapour, either in the cylinder of the engine or in some vessel external to the cylinder, and there exploded with air, much as the gas is exploded in the gas engine.

The drawback is the cost of the fuel. Refined petroleum having a calorific value of 20,000 to 22,000 B.T.U. per lb., usually costs about from 5d. to 6d. per gallon, equal to £5 or £6 per ton, so that a B.H.P. costs for fuel ½d. to ¾d. per hour. The Hornsby Ackroyd Engine will work with crude petroleum containing 19,000 B.T.U. per lb., which can be delivered in the Midlands at 2½d. per gallon, or £2 10s. per ton, and the cost of the fuel per B.H.P. per hour in that case is only ¼d. The following table, prepared by Messrs. Hornsby, who have made these engines up to 250 H.P. each, is rather unfavourable to the steam engine, seeing the coal is reckoned at 12s. per ton, while the cost of the producer gas seems excessive.

100 Brake H.P. Engines. Comparative Costs of Running.

	Hornsby-Akroyd Oil Engine.	Gas Engine, Town Gas.	Gas Engine, Power Gas.	Compound Non-Condensing Steam Engine.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Interest, depreciation, attendance, etc.	219 14 0	170 7 0	179 16 3	323 8 0
Oil, Gas, or Coal and Water for 300 days of 10 hours ...	312 10 6	540 0 0	359 17 0	458 5 0
Cost of Oil, Gas, or Coal and Water per brake horse-power per hour	0·250d.	0·432d.	0·288d.	0·367d.
Total cost per brake horse-power per hour	0·426d.	0·569d.	0·431d.	0·625d.

The above costs are based upon—

Texas liquid-fuel oil for the Hornsby-Akroyd Oil Engine at 2¼d. per gallon. This oil is at present being delivered in tank wagons alongside the Thames at 1⅞d. per gallon.

Town gas is taken at 2s. per 1,000 cubic feet, and anthracite coal for producer gas at 25s. per ton.

Steam coal is taken at 12s. per ton, and water at 6d. per 1,000 gallons.

The cost of power-gas includes interest, depreciation, and attendance at producer, in addition to fuel.

By far the most interesting engine is the Diesel, which is the outcome of a direct attempt to carry out the principles of Carnot's cycle. This engine compresses the charge of air to 500lbs. pressure per square inch, whereby it is so heated that it fires the crude oil which is blown in by air at 50 to 100lbs. higher pressure; the maximum pressure rises to nearly 700lbs. on the square inch, which makes the engine costly and necessitates its maintenance in the highest possible condition, or the compression cannot be accomplished at all. The best result obtained is 1 B.H.P. for a consumption of 0·459lb. of crude petroleum per hour.

The high thermal efficiency of oil engines is due to the fact that there is no loss due to the formation of the working fluid in a boiler or producer. This is performed in the cylinder itself, or in the Hornsby engine by the heat in the exhaust gases.

GAS ENGINES.

The small gas engine of the type which supersedes the small steam engine requires about twenty cubic feet of illuminating gas per B.H.P., and one of 50 H.P. sixteen to eighteen cubic feet in every day work, though sixteen and even fourteen may suffice under test conditions with rich

gas. Taking twenty and seventeen cubic feet respectively of gas, costing 2s. 6d. per 1,000 feet, the cost for gas works out nearly at five-10ths and six-10ths of a penny per horse power.

For situations where only a small power was required, the gas engine had very generally replaced the steam engine in 1894. This type of engine, however, was then only obtainable in small sizes, because their manufacture in this country was confined for many years, almost exclusively, to one firm who owned the patent for Dr. Otto's method of compressing the charge of gas and air before exploding it. This method of working had effected such an economy of gas as practically to drive every other form of gas engine out of the market. The patent expired in 1890, and during the past 12 years the manufacture of gas engines has been taken up by many makers, who are now prepared to supply them of sizes capable of giving several hundred horse power each, while engines giving over a thousand-horse power per engine have been constructed and worked successfully.

The cost of illuminating gas for driving engines of large size is, however, prohibitive, and this paper would be incomplete without some account of the methods employed for manufacturing cheaper and poorer gas suitable for use with gas engines, which when so fed are destined to supersede the steam engine for many purposes which have heretofore been looked upon as its own exclusive field.

The manufacture of gas from solid carbonaceous fuel is carried on by two distinct systems. (A) The retort process. (B) The producer process. This latter is again divisible into two methods. (1) Combustion with air. (2) Combustion with steam. The two latter operations are usually carried on simultaneously, but may be used separately or successively, and are susceptible of a great variety of combinations and modifications.

The retort method is that used in the gas works for making gas for illuminating purposes, and consists of charging the coal into closed retorts heated from the outside, whereby the volatile hydrocarbons are distilled off. The yield of gas which consists usually of

H	40 to 53	per cent. by volume.
CH_4	32 to 43	,, ,,
CO	4 to 8	,, ,,
Olefines	3 to $7\frac{1}{2}$	,, ,,

with small quantities of N, CO_2 and O,

is on the average 10,000 cubic feet per ton of coal carbonized, the gas containing heat to the amount of rather under 600 to a little over 700 B.T.U. per cubic foot of gas at atmospheric temperature, the quality of the gas varying with the locality from which the coal is obtained. Roughly speaking, in Great Britain the further North the coal beds are the higher is the quality of the gas extracted from the coal. In this process only the volatile portions of the coal are converted into gas, the fixed carbon, which forms

about 70 per cent. of its weight, being withdrawn from the retort in the form of coke. Taking ordinary gas coal to contain 14,000 B.T.U. per lb., and the gas to average 650 B.T.U. per cubic foot, it will be seen that such gas contains only

$$\frac{10,000 \times 650 \times 100}{14,000 \times 2,240} = 20{\cdot}7 \text{ per cent.}$$

of the heating power of the fuel, nearly 10 per cent. remaining in the tar and various products of a like nature, or being lost in the cooling process.

As the cost of distribution and purification must by Act of Parliament be carried to a point unnecessary for power purposes, it raises the selling price to an average of 2s. 6d. per 1,000 feet, but the convenience of having it "on tap" compensates for its high cost in the case of small engines.

A cheaper and poorer gas is made in the Gas Producer, where the fuel is partially burned by a current of air passing through it. Consider for the present the carbon only, which forms by far the larger proportion of all fuels, and the reactions which occur are as follows:— The oxygen of the air combines with the fuel at the bottom of the mass to form carbonic acid, thus

$$C + 2O = CO_2$$

just as in an ordinary house fire; but as a deep bed of fuel is maintained above the zone of combustion, the CO_2 in the presence of a further amount of incandescent carbon takes up a second atom of carbon to form carbonic oxide, thus

$$CO_2 + C = 2\,CO.$$

which is a combustible gas. No extraneous heat is required to effect the change from the solid to the gaseous state, because the first stage of the operation liberates more heat than is absorbed in the second stage, the surplus heat serving to distil off the hydrocarbons as in the gas retort; the fuel, by the time it reaches the zone of combustion is reduced to the form of coke. As, however, the air contains nearly four volumes of nitrogen to every volume of oxygen, the resulting gas contains about 60 per cent. of nitrogen which is inert, and serves merely to dilute it. The combustible gases of all kinds are rarely over 33 per cent. The quantity of gas produced per ton of combustible is about 130,000 cubic feet, and the calorific value from 110 to 130 B.T.U. per cubic foot, and its composition usually lies between the following limits—

CO	16·5 to 25	per cent.	by volume.
CO_2	1·5 to 10	"	"
H	5·0 to 10	"	"
N	60·0 to 66	"	"

The proportion of the potential heating power in the fuel which goes forward in the gases, that is, the efficiency of the producer, is from 60

to 70 per cent. Gas of this nature is made in the original type Siemens' producer with natural draught, and in blast furnaces, which are gas producers on a large scale. The Lencauchez producer, which is driven by fan blast, is used largely on the Continent for gasifying lignite or other wet or inferior coals, and other poor fuel, such as green wood, peat, spent tan, or sawdust, which already contain an excess of water.

Combustion of fuel with steam alone is performed by passing steam, usually superheated, through incandescent carbon, by which means the steam is split up into its constituent elements, oxygen and hydrogen, the former combining with the carbon to form carbonic oxide, and the hydrogen passing on according to the following equation—

$$C + H_2O = CO + 2H.$$

The gas thus formed is known as water gas, and the reaction is an endothermic one, that is to say, that heat is absorbed, and the temperature of the fuel would fall until it become so cold that the reaction ceased entirely, and the steam passed through the fuel undecomposed. In any process for manufacturing water gas, it is therefore necessary to supply additional heat, and the most common method is first to heat up the bed of fuel by a blast of air every few minutes, and so raise it to a condition of high incandescence, before the steam is passed through. The gas produced in the preliminary blow is of very poor quality, and is therefore thrown to waste, so that in any process of this description part of the heating power of the fuel is deliberately sacrificed, so that the remaining gas may be richer than it otherwise could be. The manufacture of water gas in this way is necessarily an intermittent one, and in practice the analyses, according to Deschamps, lie between the following limits—

H	...	46	to	58	per cent.	(by volume).
CO	...	35	,,	43	,,	,,
CO_2	...	2	,,	6	,,	,,
CH_4	...	0·5	,,	1·5	,,	,,
N	...	3	,,	5	,,	,,

The best water gas plants give a production of 70,000 to 80,000 cubic feet of gas, having a calorific value of 240 to 280 B.T.U. per cubic foot, the heat carried forward in the gas being over 75 per cent. of that contained in the fuel, or a producer efficiency of 75 per cent.

It will be seen that if the last two operations are carried on simultaneously in the same body of fuel, by supplying exactly the necessary proportions of air and steam respectively, the heat generated by the first reaction of combustion with air, might supply that needed to render the other reaction with steam possible, and the gas in that case would have the following composition—

CO	...	38·7	per cent.
H	...	16·4	"
N	...	44·9	"
		100·0	

It is impossible to obtain such a result in practice, because none of the reactions are performed perfectly, while the fuel must be maintained at a red heat or all the reactions cease, so that the gases must leave the zone of combustion at a high heat. Part of this sensible heat is usefully employed in pre-heating the deep bed of fuel above the fire, and in the case of bituminous fuel distilling off the volatile hydrocarbons as in the gas retort, which hydrocarbons, though exceedingly valuable for furnace work, are most difficult to deal with in the case of gas intended for gas engines, because they gum up the pipes and valves. The gases leaving any producer must always carry away with them a certain amount of sensible heat.

The first to take advantage of this double reaction to produce a cheap gas, fit for use in a gas engine, was Mr. Dowson, who commenced his experiments in 1879; but not till 1882 was the first Crossley engine of 16 H.P. successfully driven by this gas, made from anthracite coal. The illustrations, Figs. 5 and 6, show a plant on Mr. Dowson's principle as made by Messrs. Tangye. The gas producer, provided with a fire-brick lining and fire bars, to the left in Fig. 6, is filled about two-thirds full with small anthracite or coke, which is converted into gas by air injected below the grate by a steam jet, the steam for which is formed in the small vertical boiler shown in Fig. 5, usually fired with gas coke, and superheated by means of the coil in the pipe leading from the producer to the cooler, where the gases are cooled. Most of the dust is deposited in the box at the base of the cooler (Fig. 6) whence the gas passes through the water seal at the foot of the scrubber on the right of Fig. 6. This is filled with small coke, on which play sprays of water, the water trickling down and the gas passing up to the covered pipe at the top, whence it finds its way to the gas holder shown in Fig. 5, to be stored until required.

The yield of gas is from 150,000 to 180,000 cubic feet per ton of anthracite charged into the producer, and the heating power of the gas is from 145 to 165 B.T.U. per cubic foot.

A fair average analysis of Dowson Gas in everyday practice may be put at—

N	...	50·0	per cent.	Heating power in B.T.U. per cubic foot 158·5
CO_2	...	5·0	"	
CO	...	25·0	"	
CH_4	...	0·8	"	
H	...	18·5	"	
O, etc.	...	0·3	"	

The heating power is calculated by the approximate method of calculation usually employed, which unless otherwise stated, will be used throughout this paper.

Taking the value of the anthracite employed at 14,000 B.T.U. per lb., and the quantity of gas produced as 150,000 cubic feet, the proportion of the heating power of the fuel which appears in the gas is—

$$\frac{150{,}000 \times 158{\cdot}5}{2{,}240 \times 14{,}000} = \frac{23{,}775{,}000}{31{,}360{,}000} = 0{\cdot}758, \text{ or}$$

75·8 per cent. ; but as 20 per cent. more fuel is required to provide the steam, the actual efficiency of the whole gas-making plant would be—

$$\frac{100 \times 75{\cdot}8}{120} = 62{\cdot}5 \text{ per cent.}$$

Mr. Dowson, in a paper read before the Cleveland Institution of Engineers, says that by working with care he has obtained the following results—

	B.T U.		B.T.U.
1 lb. Anthracite ...	14,760	78·3 c. ft. of gas at 175 units per c. ft. ...	13,700
·14lb. Coke at 12,960 units per lb.... ...	1,810	Heat lost in process ...	2,870
Total heat in Fuel	16,570		16,570

$$\text{Efficiency of gas plant } \frac{13{,}700}{16{,}570} = {\cdot}827 \text{ or } 82{\cdot}7 \text{ per cent.}$$

The cost of Dowson Gas per 1,000 cubic feet, where suitable fuel is obtainable at low cost, including labour, depreciation, and all expenses, has been as low as 1½d. ; but when made from pea anthracite or gas coke in this neighbourhood, runs from 2d. to 3d. according to size of plant—2½d. may be considered a fair average. What will perhaps be better is to give the weight of fuel used per B H.P., and you can reckon up the cost yourselves.

The fuel used, including any required for the boiler, will, under test conditions, range between 0·7 to 0·8 lb. per B.H.P., or in actual, every-day practice, including stand-by losses, will run from 1 to 1¼lbs.

A firm near here, who have a plant large enough to develop 300 horse power, of which about 150 is generally in use, put the cost of a number of years running at one-twelfth of a penny for fuel, and one-twelfth of a penny for depreciation, repairs, and all capital charges, or one-sixth of a penny in all per I.H.P , and numerous other very similar cases could be cited.

One of the most obvious methods of economising heat in plants working on the Dowson system, is to recover the sensible heat contained in the issuing gases, by transferring it to the air and steam entering the producer. The waste gases from Fichet and Heurtey's producer, Fig 7, pass down the bundle of small tubes in the "interchanger" shown on the right of the cut, and in doing so give up a large portion of their heat to the air and steam which are passed around the tubes in the contrary direction. This producer itself is a modification of the Taylor producer used in some of the American steel works, and is provided with a grate set on friction balls, so that it can be revolved by a winch handle, to enable it to be conveniently cleaned. The arrangement illustrated, which is used in many places on the Continent, will make a gas of 140 to 160 B.T.U. from inferior anthracite, and one of the earliest important installations of 400 H.P for driving the electric tramways at Lausanne, consumed 577 grammes of anthracite per French horse power (equals 1¼lbs. per English H.P.),in the current actually delivered on the switch board.

The drawback to plants of the original Dowson form is that the gas holder necessary to meet a fluctuating demand takes up considerable space, and that a boiler is required which calls for constant attention, thus demanding the continual presence of an attendant. The necessity for a gas holder was obviated by M. Bénier, about 15 years ago, by arranging for the air to flow into the producer under ordinary atmospheric pressure, to replace the gas which the engine sucked in, the necessary steam being provided by the sensible heat contained in the gases. Fig. 8 shows a plant of this type made by the Dynamic Gas Company. A is the producer mounted on the ash-pan E, with cleaning door D. The boiler B consists of an annular pan with tubes depending from it, and is worked at atmospheric pressure, the water flowing slowly from the cock through the funnel Z, the surplus escaping by the syphon tube H. The air enters the jacket J around the exhaust pipe of the engine, where it is slightly heated, and passes by the pipe M over the surface of the water in the boiler down I, and through the producer, the gas leaving by the pipes S and K, through the dust catcher G, coke scrubber N, and then through the pipe T to the engine. The fuel is fed in through an air lock C (which is necessary because the producer works with a slight vacuum) into the chamber U, which contains a sufficient supply of anthracite to run the engine for three or four hours without attention. To start the producer the fire is urged for a few minutes by the hand-driven fan F, the valve L being opened to allow the poor gas at first formed to pass away to waste. The valve L is then closed, and the engine continues to draw in air just as it requires it.

The following table gives a test of a Crossley Gas Engine of 11·5 B.H.P. and 12·5 I.H.P. driven by this plant.

Starting up Producer.

TIME.	
Started to blow up Producer with hand fan ...	11-0 a.m.
Got Gas	11-5 „
Engine started ...	11-6 „
Fan stopped ...	11-6 „
Load on Brake ...	11-7 „
Engine up to speed	11-11 „
Put in first charge of fuel ...	11-11 „
Put in last charge	3-35 p.m.
Engine shut down	4-10 „
Total time of Test	5 hours.

COAL CONSUMPTION.

Best Welsh Anthracite Nuts used.

Total Coal put into Producer		74 lbs.
Ash, 4%		3 „
		71
Unconsumed large Coal	13	
„ small Coal	10	—23
Total Coal used		48lbs.

$\frac{48}{5} = 9{\cdot}6$ lbs. Coal per hour.

$\frac{9{\cdot}6}{11{\cdot}6} = \underline{0{\cdot}835 \text{ lbs. per B.H P.}}$

$\frac{9{\cdot}6}{12{\cdot}5} = \underline{0{\cdot}768 \text{ lbs. per I.H.P.}}$

COST OF RUNNING.

Coal, 32s. per ton.

$\frac{1}{7}$ of a penny per B.H.P. hour.

$\frac{1}{8}$ „ „ I.H.P. „

This is for Fuel only.

The plants are made in sizes from 5 to 60 H.P., and the makers are prepared to guarantee a consumption of 1lb. of good Welsh anthracite per B.H.P. per hour.

Messrs. Crossley make a plant in sizes up to 250 H.P. in which the steam is supplied from a water jacket surrounding the down comer, termed by them a "saturator," whence it passes to a jacket surrounding the producer, where it is further heated, both a coke and saw dust scrubber being used to purify the gas. The air is sucked in as in the previous plant, or more frequently blown in with a fan driven by the engine, the air merely revolving with the fan blades, if the producer does not require the full quantity it is capable of supplying.

The plants above described are good specimens of the leading types of gas producers using non-bituminous fuels, such as anthracite or gas coke, and in places where such fuels are obtainable at low prices nothing much better could be desired. In this neighbourhood anthracite has varied in price between 16s. and 35s. per ton during recent years, and

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may be put at 20s. per ton in normal times, while gas coke has varied between 10s. and 20s., and costs usually about 13s. per ton. Ordinary gas coke is usually considered to contain 11,500 to 13,000 B.T.U. per lb., and anthracite from 13.000 to 15,000 B.T.U., but there is good reason for supposing that the heating power of anthracite is higher, as compared with other coals, than the ordinary methods of testing for calorific efficiency show, and in practice 1¼lbs. of gas coke are required to do as much work in a gas engine as 1lb. of anthracite This makes the former usually the cheaper fuel, but there is a risk of small portions of incompletely distilled coal being found amongst the coke, which give off light tarry oils, not easily removed by washing, which are apt to give trouble in the engine: hence anthracite is usually preferred.

The problem which will interest you most as practical men is that of using our local slacks, costing 6s. or 8s. per ton, for the manufacture of gas suitable for use in gas engines, a problem which would probably have been solved years ago had engines existed of such a size as to make its use worth consideration.

The slacks of this district have the following composition:—

Moisture ...	from	5·00	to	11·00	per cent.
Nitrogen ...	„	0·90	„	1·10	„
Carbon, fixed	„	40·00	„	50·00	„
Sulphur ...	„	0·3	„	0·7	„
Ash ...	„	7·0	„	13·0	„
Volatile matter	„	28·0	„	28·7	„

Calorific value, 10,00 to 12,000 B.T.U.

These Black Country coals give in producers of the Wilson type from 115,000 to 140,000, and even sometimes 150,000 cubic feet of gas per ton, having a calorific value of 140 B.T.U. per cubic foot.

Such gas in a large steel works costs for material, labour, steam, wear and tear, and capital charges, under 1d. per 1,000 cubic feet, in some less than ¾d., and it is natural to enquire why such gas cannot be used for driving gas engines, seeing the waste gases from blast furnaces containing only from 90 to 110 B.T.U. per cubic foot have been employed for this purpose for some years past.

The difficulty, as you are aware, is the presence of so much volatile matter in the coal, which on the application of heat forms tars and oils, which condense, choke the pipes, and gum up the engine. These volatile matters are supposed to have been slowly distilled from the anthracite by volcanic heat ages since in a manner very similar to the distillation of coal in a retort, except that the material was subjected to enormous pressure during the process. Of the tarry matter in the bituminous coal 5 per cent. is bound to be lost in the washing of the gas, so that if we put the consumption of anthracite per H.P. at 0·7 lb. on test, or 1·1 in daily running, we may expect the consumption of

local slack to be about 1 lb. under test conditions, or 1·7 lbs., including stand by losses in every day practice. On this basis the saving obtainable in a plant of 500 H.P. working 300 days of ten hours each per annum would be

	£
$500 \times 1{\cdot}1 \times 300 \times 10 = 1{,}650{,}000$ lbs. $= 737$ tons @ 20s.,	737
$500 \times 1{\cdot}7 \times 300 \times 10 = 2{,}550{,}000$ lbs. $= 1{,}138$ tons @ 7s.,	398
Saving per annum due to use of bituminous slack ...	£339

The first to succeed in making a gas suitable for gas engines on a commercial scale from bituminous slack was Dr. Mond, who in the process of extracting ammonia from coal made enormous quantities of washed producer gas, from which the tars and oils were removed by the washing process; he used a small portion of it to drive two gas engines at his works at Winnington, about the year 1894, and every credit is due to him for the first practical solution of the problem.

According to Mr. Humphrey ("Proc. Inst. C.E.," Vol. CXXIX.), the analysis of the coal used by Dr. Mond is

Moisture	7·3	per cent.
Nitrogen	1·29	,,
Carbon, total	67·88	,,
Sulphur	1·30	,,
Ash	7·57	,,
Volatile matter	14·66	,,
	100·00	

Calorific value per lb. in B.T.U., 13,000.

the gas formed from it having the following composition—

Hydrogen	24·8	Calorific value 154·6 B.T.U per c. ft.
CH_4	2·3	
CO	13·2	
N	46·8	
CO_2	12·9	

The gas made from a ton of fuel charged into the producer being about 160,000 cubic feet.

As you will see, this fuel contains more nitrogen, but only half the volatile matter in our local slacks, and is, therefore, more easily dealt with. The H and CO_2 are always high in any producer worked with an excess of steam, and as Dr. Mond passes $2\frac{1}{2}$ tons of steam through his producer for every ton of coal gasified, instead of about $\frac{3}{4}$ ton, usual in Dowson producers, the proportion of these gases is not surprising. Mr. Humphrey gives the efficiency of the producer as 81 per cent, on the coal gasified; but as quite $\frac{1}{4}$ ton of fuel would be

required to supply the 2½ tons of steam, the efficiency on the total fuel used could hardly be more than $\frac{81 \times 20}{25}$ = 64 per cent., or much the same as is obtained in most other producers working with bituminous slack; but less than the best results which have been obtained with nuts of good quality. Mr. Duff has had a very similar plant, but somewhat simplified, at work for four years at the United Alkali Co.'s Works, at Widnes.

Both of these plants recover so much ammonia from the coal as suffices to pay a considerable proportion of its cost, and there is no doubt that they can produce a suitable gas, costing for fuel alone about 0·4d. per 1,000 cubic feet, or including depreciation, renewals, and capital charges, say 0·65d., when working for 8 hours out of the 24. At least two other firms are prepared to construct recovery plants on somewhat similar lines.

The only drawback to these recovery plants is that they must be constructed on such a gigantic scale as to exceed the requirements of power in any ordinary works, and, as you are aware, to meet this difficulty, works are now under construction only a mile or two from this room, from which it is intended to distribute producer gas for purposes of heating and power over almost the identical district for which Sir Wm. Siemens applied for Parliamentary powers for a similar scheme a generation ago.

It is understood that the Mond Company propose to sell their gas at 1½d. and 2d. per 1,000 cubic feet, and say that at the latter price the cost of sufficient gas to give a horse power for one hour, will be ⅛d., which the value of the gas shows is likely to be the case with large engines.

The success of this, as of any other gas company, depends upon its ability to deliver a suitable gas to customers at such a price as will dissuade them from making the gas for themselves on their own premises. In addition to the economies due to every manufacture on a large scale, the Company will have the advantage of recovering the ammonia, which the small manufacturers at present cannot do, against which must be set the cost of management and distribution. The latter expense the Company hope to reduce considerably by delivering at a pressure, it is understood, of some 6lbs. on the square inch, which is the only chance of keeping this cost within possible bounds. It may, however, cut both ways in a district the surface of which is liable to disturbance by mines.

The next to attack the problem was Mr. Alfred Wilson, the inventor of the Wilson producer, so well known to every iron and steel works' manager, who had a plant at work five years ago. Mr. Wilson makes no attempt to recover the ammonia, or wash the gas. Fig. 9 shows his plant now at work at the Horsehay Works. On the right of the cut is the producer, next it a large box containing what is practically a set of

Green's economiser pipes, furnished with scrapers to remove the tar. Next are a set of cooling pipes, then a sawdust scrubber, and lastly the gas holder, twenty-five feet in diameter. The air is driven into the producer by a small Root's blower, the exhaust steam from the engine to drive which is mixed with the air, the mixture passing through the economiser pipes, where it is heated by the gases leaving the producer, which play on the outside of the pipes. The gas is cooled, and then purified by sawdust, no washing whatever being attempted, Mr. Wilson considering that washing the gas causes a loss, and involves difficulties without sufficient compensating advantages.

A Shropshire coal (a sample of which is on the table) is employed, costing 7s. 6d. per ton delivered, an analysis of which (as of the two samples to be given later) was kindly made for the writer by Mr. H. Silvester.

Fixed Carbon	46·44	per cent.
Volatile matter	30·00	„
Ash	8·30	„
Sulphur	0·73	„
Moisture	14·53	„

Calorific value in B.T.U. per lb, 10,737.

The gas made from it has a calorific value of 140 to 150 B.T.U. per cubic foot, and the consumption of the former quality is said to be about 80 cubic feet per B.H.P., about the same as that of Mond gas of the same calorific efficiency.

The plant in question is large enough to furnish gas for 300 H.P., but about 269 is used in five or six engines, and the consumption of slack charged into the producer is 254lbs. = 0·94lbs. per I.H.P. per hour. To this must be added the coal making steam to drive the blower, which is said by the makers to take 2 H.P. Assuming a consumption of 60lbs. of steam per I.H.P., and that the boiler evaporated 5lbs. of water per lb. of coal, this would amount to 24lbs. per hour additional, or a total consumption of—

$$\frac{254 + 24}{269} = 1{\cdot}03\text{lbs. of slack per I.H.P. per hour.}$$

Mr. Wilson writes that one of his power plants using Erewash Valley slack, was tested by independent parties, and gave the following results—

N ...	54·0	per cent.	B.T.U. per cubic foot, 161.
H ...	15·0	„	
CO_2 ...	3·7	„	
CO ...	25·9	„	
CH_4 ...	1·4	„	

and that one of his plants which replaced a high-class Sulzer engine is effecting a saving in the fuel bill at the rate of £700 per annum.

Fig. 10 shows Messrs. Crossley's plant, which is at work at Messrs. J. & E. Wrights in Birmingham where by the kindness of Mr. G. Turner the Managing Director,, the writer was enabled to see the plant in operation. A gas engine which is started and driven for 10 minutes each morning by town gas, and after by the producer gas, drives an air compressor, which delivers the air into the air tower, through which is sprayed hot water taken from the washer, thus warming the air and saturating it with moisture. the mixture passes to a heat interchanger, very similar to Fichet and Heurtey's, then into a jacket round the producer and below the grate of a producer practically similar to theirs. The gas leaving the producer, after passing the interchanger, enters the washer, which is divided into halves, and provided with splashers very similar to those used in the Mond plant. On leaving that it passes up three washing towers, filled with watered coke, very similar to those in the Tangye plant already illustrated, and from them to the tar extractor, which consists of a revolving disc with radial blades, the gas entering on one side and leaving on the other, and thence it passes to the sawdust scrubbers, and is delivered direct to the engines, of which at present two are at work.

A Warwickshire slack is used costing 5s. 9d. per ton delivered, a sample of which is on the table and its analysis is—

Fixed carbon	41·03	per cent.
Volatile matter	32·60	„
Ash	12·70	„
Sulphur	3·57	„
Moisture	10·10	„
	100·00	

Calorific value in B.T.U. per lb., 11,175.

Messrs. Crossley say that out of 15 per cent of volatile matter, 10 per cent. is removed in the form of tar and oil. The following are two analyses, made for Messrs. Crossley before the parts were covered with non-conducting composition, and the value of the gas—

CO_2 ...	3·5	185 B.T.U.	CO_2 ...	3·4	200 B.T.U.
CO ...	28·8		CO ...	28·9	
CH_4 ...	2·2		CH_4 ...	3·4	
H ...	17·6		H ...	17·74	

They report that 180 B.T.U. may be regarded as a fair average gas to be got from bituminons slack, a better quality of gas than they can get from anthracite. From 55 to 75 per cent of the sensible heat of the gases is recovered in the washing water. They consider they get

115,000 to 145,000 cubic feet per ton, according to the value of the fuel, which on an average would mean a consumption of not more than 1lb. of coal per B H.P. per hour.

A third method of manufacturing gas suitable for gas engines from bituminous slack is to split up the tarry matters which cause the trouble into permanent gases by passing them through incandescent carbon.

Numberless methods for accomplishing this have been devised from time to time and have been attended with more or less success, such for instance as driving the air down the producer instead of up it, so that the gases pass through the incandescent zone last. Feeding one side of the producer with coke, through which the gases from the other half must pass, or passing the gas from the first producer through a second filled with coke, and using twin producers with or without regenerators or secondary air supply, the current passing up the one and down the other producer alternately. Mr. B. H. Thwaite by modifications of some of these methods succeeded in getting down the consumption of bituminous slack to 2 lbs. per I.H P.

The writer has recently seen in operation a very simple plant Fig. 11, made by the Industrial Engineering Company which burns the tars in this way and produces a species of water gas from common slack. The operation is as follows. The producer on the right is provided with a coil of pipe in its upper portion, to which water is supplied by any suitable means, at a pressure of 60 lbs. on the square inch. The steam is used in an injector to blow up the fuel, the necessary air entering through a grating provided with an internal flap which closes against internal pressure, similar to one shown on the top of the producer.

The poor gas passes to waste up the chimney, and when the fuel is sufficiently hot, the jet is reversed and drives the steam downwards through the fuel forming water gas, a small portion of air passing in with the steam assists in the combustion of the tar. The gas passes through a water seal, up the small coke washer shown, and then through the saw-dust scrubber to the regulating holder, and thence to the engine. The object of the regulator holder is to automatically reverse the action in the following manner. While the bed of fuel is being blown up and no gas is being made the engine draws from the regulator holder, which, when it has fallen to a certain point trips the reversing valve by means of the cord, when the water gas is made and passes into the regulator faster than the engine can use it, until the regulator rises so high that the valve is tripped in the other direction, and the blow up again occurs.

These reversals take place about once a minute.

The following is the analysis of the gas and its heating power, as calculated by Mr. Lester, the gas expert of Manchester—

			B.T.U.
CO_2	...	5·6 per cent.	—
C_2H_4	...	·6 ,,	10·044
O	...	·8 ,,	—
CO	...	33·2 ,,	113·666
CH_4	...	3·6 ,,	38·340
H	...	43·2 ,,	149·040
N	...	13·0 ,,	—
			311·090

And the following an analysis, by Mr. Silvester, of the fuel used—

Fixed Carbon	...	51·11	per cent.
Volatile matter	...	32·97	,,
Ash ...	... ...	5·20	,,
Sulphur	... ...	1·79	,,
Moisture	... ..	8·93	,,
		100·00	

Calorific value, 11,800 B.T.U. per lb.

The Company state that the cost of the fuel per 1,000 feet of gas is only 2d., and the consumption of fuel about 1¼lbs. per H.P. per hour.

The plant illustrated is suitable for a 10 H.P. engine, and is particularly interesting because the quality of the gas enables an engine to be used which need not be appreciably larger than one for use with illuminating gas, whereas engines using Dowson or other producer gas require to be 15 to 20 per cent. larger, on account of the large quantity of inert nitrogen contained in the gas. Moreover, the same gas can be employed for welding, for which gas of 160 B.T U. will not give a sufficiently high flame temperature, although it is understood that Mr. Fletcher, of Warrington, has succeeded in using Dowson gas to a limited extent in a blow pipe.

It is not improbable that there will soon be as many makes of gas plants as there now are of gas engines. Anthracite plants are likely to hold their own for small sizes, because they can now be arranged so as to need attention only once every three or four hours, a condition which it is scarcely likely can be attained with bituminous coals, because they stick together when heated, and so cannot be relied upon to slide down a hopper as the material below is consumed. We may feel sure though that for driving large engines, gas made from bituminous slack by some process will be employed extensively in the future.

It has been fashionable of late to ridicule the steam engine as an antiquated monstrosity fit only for a museum, its efficiency being 12 to 15 per cent. at most "in the very best makes and largest sizes driven by picked coal, and its efficiency in small sizes perfectly ridiculous," whereas we have

been told that the efficiency of the gas engine is 20 or 25 per cent., even 30 per cent is sometimes mentioned "even in the small sizes." It is not mentioned, however, that the efficiency of the steam engine has been always calculated on the thermal units contained in the coal, while it has been customary to reckon that of the gas engine on the thermal units contained in the gas. If one is debited with losses in the boiler surely the other should be with losses in the retort and producer. To make the real facts clear the writer has prepared the diagram Fig. 12, showing where the heat in the coal goes. Judged on this basis, the small engine run with town gas requires the raising of pretty nearly as much coal as the small steam engine, and the large one worked with an equal quantity of fuel requires not so very much less than the steam engine, which, up to the present, has been able to use up fuel which the gas engine could not employ at all. As nearly as can be judged, the proportion of coal used in this country in steam engines which could conceivably be now replaced by gas engines, is not more than one fourth of the whole quantity of coal raised in the United Kingdom. It would not, therefore, be possible by throwing our steam engines on the scrap heap, and putting down gas engines in their place, to extend four or five fold the period during which our fuel supplies would last, as some amiable enthusiasts, usually possessed of more imagination than knowledge, would try and persuade us.

Stripped of ridiculous exaggeration the fact remains that the gas engine is distinctly more economical than the steam engine, and as the exhaust gases leave at a very high temperature, there is more opportunity of utilising the heat they contain than is the case with the steam engine, and the possibility for future improvement in the gas engine lies probably in this direction Wilson has already succeeded by their use in raising steam in special boilers, but some form of regenerative action is what seems likely to give the best chance of success. The most serious cause of loss in the gas engine is that due to the cooling of the jacket by the circulating water, which carries away about one half of all the heat supplied to the engine. So long as we use a cylinder and piston which must be kept sufficiently cool to prevent undue friction and wear, there seems little hope of discovering any cure for this, but it is possible that the use of a turbine similar to Parsons' steam turbine, in which there are no rubbing surfaces in contact, might enable the interior of the engine to be maintained at such a high temperature as to avoid part, at least, of this loss.

At present the steam engine can only compete with the gas engine for consumption of fuel in the case of the larger sizes, because to approach it in economy the latter requires much complicated plant in the forms of pumps, economisers, superheaters, etc. Moreover the gas engine does not fall off in efficiency as it decreases in size, with anything like the rapidity of the steam engine, so that while several small steam engines

dotted about a works driven by a central battery of boilers is a very uneconomical arrangement, several small gas engines driven from one battery of producers would not be, but on the contrary is likely to be a serious rival to electric transmission in a works of moderate size.

Comparing the gas producer with the steam boiler, with its chimney and setting, the first cost is less, and the wear and tear immensely less, while its efficiency is rather higher than that of the steam boiler. The small boiler has an efficiency of only 50 per cent, an average good boiler 65 per cent, and the best, with economiser and modern requirements, 80 or very rarely 85 per cent, while the ordinary slack producer has an efficiency of 65 per cent, rising with careful working to 75 per cent, and a Dowson type 70, rising with care to rather over 80 per cent.

If no gas holder is used, the space occupied by both plants is not very different.

The first cost of a gas engine is somewhat less than that of a high-class steam engine of the same power, and the wear and tear much the same—if anything in favour of steam.

Gas engines, however, have their drawbacks. In the first place, they are difficult to start, must be run at one particular speed, and cannot be reversed, conditions which alone would prevent their use for propelling ships; nor are they so suitable for pumping as the present type of steam pumping engines, which can be run at the exact speed needed to supply the amount of water required. The same objection applies to the use of gas engines for the supply of compressed air, or water, at hydraulic pressure, for which purpose steam engines are able to adjust themselves precisely to the requirements of the case, stopping and starting, or running at any speed as the demand fluctuates. Nor are gas engines suitable for winding engines in collieries which must be capable of the most exact control as to speed and reversal, or life will be endangered, nor for rolling mills in our steel works, where engines must be reversed several times in a minute. There is reason to doubt if any engine driven by an explosive force can ever be under the same control as the steam or other engine in which there is a steady reserve of pressure upon which to draw to any extent desired, for which reason gas engines are unlikely to supersede steam engines for many purposes, where great or frequent variation in speed is requisite, but for other purposes they undoubtedly have a great future before them.

In conclusion, the writer wishes to express his thanks to those gentlemen who have provided him with information and have lent blocks for the purpose of illustrating this paper, and particularly to Mr. Silvester, who kindly volunteered to make the analyses of some of the fuels.

CORRESPONDENCE.

THE SECRETARY announced a telegram from Mr. B. H. Thwaite, who characterised the description of his producer as inaccurate and misleading. In other respects he agreed with the paper and considered it valuable.

The following letter was then read from Mr. Horace G. Hills (The Industrial Engineering Company) :—

There are points in your paper to which I would like to call attention, and trust you will not consider it out of place for me to offer a small amount of criticism.

On page 92 you give the relative costs of gas, oil, and steam engines. I do not wish to offer any remarks as to the cost of running on town gas or steam engines, but the figures given for producer gas are certainly, in my opinion, incorrect. Of course I recognise that the figures are not your own, but those given by Messrs Hornsby. The following is my estimate of the cost of running a 100-horse gas engine on "Simplex" producer gas :—

Cost of 100 B.H.P. engine and tanks ... £450. Interest and depreciation, at 20 per cent.		=	90	0	0
Cost of 125 B H.P. Simplex Producer, with large storage holder, complete . £900. Interest and depreciation, at 15 per cent.		=	135	0	0
Cost of fuel, 3,000 hours × 100 B H.P., at 1lb. per B.H.P. hour = 134 tons. Add 50 per cent. for non-working hours and contingencies = 67 tons					
	201 tons at 7/-	=	70	0	0
Attendance on producer and engine: 50 weeks @ 25/- for man. 50 weeks @ 7/- for boy. 32/-		=	80	0	0
	Total		£375	0	0

Equalling 0·3 penny per B.H.P. hour.

In this estimate you will notice that the interest and depreciation of the gas producer is taken at 15 per cent. per annum, which is far more

than is really necessary and the interest and depreciation on the gas engine at 20 per cent., which is certainly ample. You will also notice that though the cost of fuel per B.H.P. hour during the working time is only 1 lb., I have considered it advisable to add 50 per cent. to account for the hours when the producer is not working and for contingencies. This, however, is considerably more than our experience has shown to be actually necessary, provided the working is careful. The attendance of labour required for the producer is very little indeed, and a man and a boy could certainly look after both the engine and the producer. You will thus see that the cost per B.H.P. hour, after allowing these ample margins, is only ·3 of a penny instead of ·431 as estimated by Messrs. Hornsby. Larger powers would be very much less.

On page 105 you are kind enough to mention the Simplex gas plant, and I should be much obliged if you will allow me to remark that there are one or two errors, and also that a portion of your statements might lead to an incorrect appreciation of the plant. On line 3 in the fourth paragraph of this page you state "a small portion of air passing in with the steam which assists in the combustion of the tar." This is not quite correct, as during the gas making no air whatever is admitted, and the tar is volatilised and fixed as a permanent gas during its passage from the top to the bottom of the producer.

On the following page you state that the cost of the fuel per 1,000 ft. of gas is only 2d., and that the consumption of fuel is about $1\frac{3}{4}$lbs. per B.H.P. per hour. This consumption is estimated for a 10 B.H.P. size only, whereas in larger sizes, say 100 H.P., the consumption is only 1lb. per I.H.P.

In the next paragraph you remark that "engines worked on this gas do not have to be appreciably larger than those used with illuminating gas." There is no necessity for the engines to be any larger; in the 10-horse size exactly the same power is given off as when town gas is used, and in larger sizes rather more power is developed by the engine than if worked by town gas. The analysis given is the analysis of the gas made in a 10 H.P. plant, and as it may be of interest to you, I append the analysis of a plant of 125 H.P.:—

CO_2	...	...	...	8·0	per cent.
C_2H_4	...	...	...	·4	"
CO	...	...	...	30·5	"
CH_4	...	...	...	7·0	"
H	...	...	...	47·5	"
N	...	...	...	6·6	"

This gives a calorific value of 350 B.T.U. The analysis is not a picked one, as we have obtained better results giving a calorific value of 380 B.T.U. The quality of the gas made by this producer can be varied to suit requirements, but the quality of the analysis giving 350

B.T.U. appears to be the one by which the greatest efficiency from the fuel is obtained.

Further down on the same page you remark that "anthracite plants are likely to hold their own for small sizes because they can be arranged so as to need attention only once every three or four hours, a condition which is scarcely likely to be attained with bituminous coal." We find that a 10 H.P. plant can be arranged so as to require attention only once every hour, and we are under the impression that if an anthracite plant, or any other plant of this size, were left for a longer period, the quality of the gas would vary very considerably, *i.e.*, immediately after recharging the gas would fall 30 per cent. or 40 per cent. in calorific value. In suction plants, where combustion is created by the engine sucking in the air and steam through the fuel, it is almost imperative to keep the fuel in a constant and regular state, as if this is not done, the back pressure at the gas valve will be the greatest when the gas is the worst, that is to say, when the new charge of fuel has been put in, so that the engine will draw in less gas and more air when the reverse is required. This accounts for the very great excess of reserve power required in an engine working on the suction producer principle. I have been informed by several of the leading gas engine makers in the country that the loss of power in an engine working on a suction producer as compared with one working on town gas, is between 40 and 45 per cent. Bearing this in mind, it will be seen that if 30-horse power should be required it would be necessary to provide an engine of 50-horse, so as to be able at all times to abtain the 30-horse which is actually required. This is a great consideration, as it increases the cost of the engine by something like £100.

With our larger plants, where the system is slightly different to that employed in the smaller ones, we supply special washers for taking the tar out of the gas. Both the system and the plant have been thoroughly patented, but the process is more or less as follows:—The washer consists of a vertical cylinder, having down its length, at intervals of about one foot, cross plates with a hole in the middle of each. Down the centre of the cylinder is a rotating shaft, attached to which are a number of flat plates, which project between the plates fixed to the cylinder. The gas enters at the bottom and passes upwards, being drawn outwards by the centrifugal force of the friction of the rotating plates, and is brought to the interior again by the fixed baffles, being again drawn outwards by the next rotating plate, and so on until it reaches the exit at the top. At the same time that the gas enters at the bottom, common gas oil is admitted at the top. This falls successively from plate to plate, and is dashed outwards in a fine spray against the gas, the oil coming out at the bottom of the washer through a syphon pipe into a round tar well. The oil is discharged in this tar well at a tangent, and swirls round and round. The tar, being heavier, goes to the side and

the oil comes to the centre, running down a pipe connected with a centrifugal pump, which raises it again to the top of the washer. We have found that this is a perfect form of washing gas, extracting from it all the tar, which, strangely enough, it deposits in heavy clots at the outside and bottom of the tar well from which it can be raked without any trouble whatever. The oil is used over and over again.

Since we had the pleasure of seeing you here, we have been making experiments with wood as a fuel in our producer, with the following result:—The calorific value of the gas produced is 280 B.T.U., and the quantity required per B.H.P. about 6 lbs.

In conclusion, I wish to congratulate you upon the very interesting paper which you have prepared, and I am sure that what you have written will be very much appreciated.

THE DISCUSSION.

Mr. T. Rigby said: All must feel indebted to Mr. Hall for his very able paper.

He then called attention to the figures quoted of a plant made by the Dynamic Gas Company, showing the coal consumption, using best Welsh Anthracite nuts, to be 0·835lbs. per B.H.P. hour on a five hours' test Messrs. Crossleys had a report sent them of an independent consulting engineer's test of one of their small plants, working in the south of England on anthracite coal. On a 30 hours' continuous test, the consumption was 13lbs of fuel per hour, with an electrical load of 85 amperes at 140 volts pressure. This averaged 0·81lbs. of fuel per E.H.P. at the dynamo terminals, and 0·729lbs. per B.H.P. on the engine.

The author had mentioned in his paper that cheap gas was being made in hundreds of works for heating purposes from Black Country coals, but was not suitable for gas engines owing to the tar present with the gases. It might interest them to know that his firm were were prepared to put down an inexpensive form of cleansing plant to enable such works to obtain power from the same flues as the heating supply, provided that the gas was anything like constant in quality. Mr. Rigby proceeded to point out that the minimum heat value of Mond gas allowable in the Staffordshire Power Gas Bill was 125 B Th.U. per cubic foot, and that in all probability the gas supplied to customers would be nearer that figure than the higher one mentioned in the paper as 154·6 B.Th.U. per cubic foot. It would pay the company to do this, since when making the gas of lower heating value, a larger yield of sulphate of ammonia was obtained in the process. The prices mentioned in the paper, as those at which it was understood the Mond Company proposed to sell their gas, namely 1½d. and 2d, per thousand cubic feet, were low. In all probability the price would be nearer 3d.

:housand, when using not less than 16 million cubic feet per annum, if using a lesser quantity, 4d. per thousand would have to be ged. The figures mentioned, namely, 16 million cubic feet, would bout equal to an engine of 50 B.H.P. working 300 days of 10 hours rear. It might, therefore, be taken that engines working 3,000 's per year below 50 H.P. size would be supplied at 4d. per thousand, at and above that figure, at 3d.

e (Mr. Rigby) wished to protest against the comparative figures 1 on page 92 of the paper, and supplied, he understood, by Messrs. ısby. He had prepared a revised comparative list of figures, ıding that of Mond Power Gas, supplied to an engine of 100 B.H.P., ;d. and 3d. per 1,000 cubic feet. He had not altered the Hornsby 'oyd oil engine figures or those of the steam engine. This revised ment was as follows:—

B.H.P. Engines.—Revised comparative costs of running for one year.

	Hornsby Ackroyd Oil Engine.	Gas Engine, Town Gas.	Gas Engine, Power Gas.	Compound Steam Non-cond. Engine.	Mond Gas at 1½d. per 1,000 cubic feet.	Mond Gas at 3d. per 1,000 cubic feet.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
est, recia-, At-ance, ...	219 14 0	100 0 0	155 0 0	323 8 0	110 0 0	110 0 0
ɪas, or and ;er, for lays of ɔurs ..	312 10 6	460 0 0	72 10 0	458 5 0	160 0 0	310 0 0
of Oil, or and er per .P. per ...	0·250d.	0·368d.	0·058d.	0·367d.	0·128d.	0·248d.
cost 3.H.P. ...	0·426d.	0·448d.	0·182d.	0·625d.	0·216d.	0·336d.

ith regard to this table, interest and depreciation on the capital is as 10 per cent. in the cases of town gas and Crossley engine, sley Patent type B. power gas plant and engine, and gas engine ing on Mond gas. Town gas is taken at 2s. per thousand feet and

bituminous coal or slack for gas producer, at 6s. per ton. Water is taken at 6d. per 1,000 gallons. In every case attendance of a man at 6d. per hour is allowed for. In the case of gas plant and engine, one man could attend to both with ease. It would be seen that the cost of working the Crossley installation was remarkably low. Whilst the figure for interest, depreciation, and attendance in the case of the Hornsby oil engine was £219 14s. od,, Messrs. Crossley could do it for £155 ; and whilst their cost of working for 300 days was £312 10s. 6d., Messrs. Crossley's was only £72 10s. od. (a large difference). Then again, the cost of motive power per B.H.P. came out 0·058d., as against 0·250d., whilst the total B.H.P. hourly cost came out at 0·182d., as against 0·426d. for the Hornsby oil engine.

The Crossley power gas installation was also much cheaper (as shown by the table) than when Mond gas, even at 1½d. per 1,000 cubic feet, was employed. There was, in fact, a great difference in the figures. On page 103, it was mentioned that in the Wilson system of gas cooling, the gas was not cooled directly by water, but by what is known as the atmospheric system, which Mr. Wilson considered better. He (Mr. Rigby) did not agree with him in this respect. If the gas was cooled by water, it could be done at far less cost than the Wilson system, and the gas was obtained very clean before leaving the washing plant, which was not the case in the Wilson plant. He had recently seen a design for a Wilson plant, and in that provision had been made for washing the gas previous to entering the final purifier, so it seemed Mr. Wilson was coming round to these views.

Mr. Rigby observed that he agreed with the author as to the wisdom of having separate units of gas engines driven from one battery of gas producers for large works. That was a far better method, in his opinion, than the electrical system, and his company found it cheaper than electrical driving. In respect to the reliability of gas engines, he gave an instance of one Crossley gas engine which had run six months without stopping at all. Its performance has been commended in a paper before the Institute of Mechanical Engineers, since which time he understood it had broken all previous records and had run for something over ten months. As to the wear and tear of a gas engine, that depended to a large extent upon the mechanical efficiency of the engine. As a proof of the high mechanical efficiency of the Crossley engines, he would point to the figures given by Mr. Hall on page 99 of his paper, showing tests of a Crossley gas engine driven by a gas producing plant built by the Dynamic Gas Company. It was a fact that they got out of this gas engine a mechanical efficiency of 92 per cent. He did not think a steam engine of the same size could be got to do that. As to varying the speed of a gas engine, his company had several patent arrangements for varying the rate of running to anything between half speed up to full speed,

He noticed that in the correspondence contributed to the debate, exception was taken to some of the Crossley figures, but he could assure them they were correct. They did not claim an average of more than 180 British Thermal Units, and the highest analysis given, viz., 200 B.T.U., was due to the higher percentage of CH_4 present, owing to the producer at the time being filled with new fuel. He had known claims made by other makers of as much as 188 British Thermal Units, and he believed that had been done occasionally, but they got 180 in their own works regularly. They had a far larger grate area than in the majority of gas producers. Anyone, for instance, who had worked the Wilson producer, would know the tremendous quantity of clinker that had to be dealt with, and that was in a great measure due to the small grate area allowed. In the Wilson grate there were a number of small tuyeres on each side of the central casting. In the producer made by his firm, they had something like ten times the grate area, with correspondingly better burned ashes and gasification. There had lately been a great demand for suction plants, though they believed it was better in most cases to work on pressure. He did not agree with those who held that from 40 to 45 per cent larger engines were required to work on gas from a suction plant than on coal gas; 20 per cent. would be nearer the mark.

Mr. H. Le Neve Foster: I should like to ask if Mr. Rigby was putting down a 50 H.P. gas-producing plant, whether he could work it occasionally at only 10, 20, or 30 H.P., to suit varying loads on the engine?

Mr. Rigby: Yes, we could on bituminous coal, or coke. We could vary the power to meet the necessities of the load, and could get down, if necessary, to as low as one-seventh of the maximum H.P. of the plant.

Mr. Herbert Pilkington: I am one of those unfortunate persons who have to use both steam, gas, and oil in engines, and the resulting controversy is not conducive to one's peace of mind. I must congratulate Mr. Hall upon his very interesting paper. The discussion as to the comparative merits of oil, gas, and steam, reminds me of hundreds of discussions on the same matter which I have had to go through at the works with which I am connected during the past three or four years. I don't think Mr. Hall has put before us the most favourable view of the gas engines; but perhaps he has put the most favourable view of steam engines. I am very glad he mentioned the "tall talk" one sometimes meets with, with regard to what is possible with gas engines, and with reference to the so-called wisdom of "scrapping" steam engines in favour of gas. You will be pleased to learn that only last Saturday, at the Manchester Association of Engineers, one of the speakers informed the meeting that pig iron was going to be produced from 5s. to 10s. per ton cheaper

than before, because of the economy effected by the use of gas engines worked by blast-furnace gas. I learnt also, at the same meeting, that poor gases were more liable to ignition than richer gases. In fact, all sorts of wild things are said by some gas engine advocates. With reference to Joule's equivalent, this should, I think, be taken at the figure 778. With regard to the contrast between steam and gas engines, the Research Committee of the Mechanical Engineers, taking Carnot's formula, give the highest theoretical efficiency as 87 per cent. for gas engines and 56 per cent for engines worked by superheated steam. Of course neither figure will ever be reached in practice, but it is evident that theoretically, and in my opinion, from every point of view, the gas engine, as a heat engine, is bound to win ultimately, and already is a better thermal engine than the steam engine. In his comparisons, Mr. Hall seems to have dealt with relatively small plants in gas engines but not in steam engines. In one place he says "a compound steam engine of say 300 H.P., of good construction, can be made to work with about three pounds of slack" per indicated horse power, and he says a reasonably good factory engine need not take more than 5lbs. It is not an easy matter to get 3lbs. of slack to produce one indicated horse power. He must admit that it has to be a very well constructed plant that will do that As to town gas. Except in towns like Northampton, away from coal fields, the future of gas engines does not depend upon town gas. It depends upon producer gas, or blast furnace gas, which are both cheap gases. I see no particular reason, either, for straining after high calorific value in gases. In this country gas engine builders have had great chances, but have not risen to the occasion. With one or two exceptions, I don't know of any gas engine builders who have much knowledge as to the best way to build gas engines of large power for poor gases; but in Germany there are builders of large gas engines, ranging from 500 up to 2,000 H.P. They have risen to the occasion very much better than British gas engine builders. I was very much struck with the remarks with regard to the control of gas engines. I have had to work them for two years, and they are being run now by engine-minders who never drove any engines of any kind in their lives before. I may also point out that the control arrangements are very good in some of the newest types of gas engines, especially the large sizes. I don't suppose that Mr. Hall will allege that gas engines of that description cannot be regulated and controlled properly. In the Körting type of engine, with an explosion every revolution, the regulation is effected by controlling the amount of mixture per admission, and there are many others that do this. Mr. Hall seems to think that engines using weak gas do not require to be of a larger size than engines using rich gas; but I think they do. The real reason why there have been cases of premature ignition in gas engines on poor gas is the very high degree of compression which is put upon the gas, and this necessitates that in all cases the ignition should be under the control

of ignition valves. The size of engines has a very material bearing on the whole matter. Small gas engines should be compared with small steam engines, and large with large. What is wanted is the comparison of small and medium sized gas engines, with steam engines of 10, 20, or 50 H.P, It is perfectly clear that the cost of fuel consumption of steam engines of that size must be more than gas engines of corresponding powers. To arrive at a correct estimate we must consider on one hand the production of the gas, and on the other the production of steam. I should also say that small gas-producing plants, producing gas for gas engines, have not, so far as I know, been altogether a success. A point has been made of the circumstance that the capital cost of cleaning bituminous gas is considerable. It is very questionable whether these small generating plants, using bituminous coal, are as economical as having the clean gas "on tap," just the same as town gas, or Mond gas. Taking a hundred H.P. plant, and the cost of the steam engine and boilers for duplicate running—for a hundred H.P. plant, taking producers, cleaning plant, and engines and everything, and taking the steam engine as compound condensing—I found that a gas engine plant might have been put down for something like £2 10s. per indicated horse power less for gas than steam, in the original cost of the plant. Now, assuming the fuel consumption for the steam plant to be 5lbs. of fuel per indicated horse power, and assuming an expenditure of considerably more fuel than any of the speakers have allowed to-night in the gas producers, I found that the running expenses were one-third less for the gas plant than for the steam plant. [Mr. HALL : Using anthracite, I suppose ?—Mr. PILKINGTON : No, using bituminous slack.] Mr. PILKINGTON : At our works, although we can in case of necessity turn on other gas, we run our gas engines with waste gas from our blast furnaces. It, therefore, resolved itself into a question of gas engines and cleaning plant only, and we found that the economy lay altogether on the side of the gas engine, by a large amount. Then Mr. Hall suggests that many drawbacks are attached to gas engines, and amongst them he mentions that they have not been adopted for driving rolling mills because it would be difficult to reverse them. But as against this, we must remember that it is not all mills that need to be reversing. The Kőrting engine has been attached to a 3-high mill in Germany, and is being worked by gas. There was also one at Dusseldorf Exhibition Mills may be reversed by other means than reversing engines so as to use continuous running engines. Very efficient clutches are now in the market. Of course you could not run a winding engine with a gas engine. But it seems to me that each class of engine—both steam and gas—have their own spheres, and that a great deal of economy is likely to result from the employment of the gas engine in many cases. We have two 100 nominal H.P. gas engine at Sheepbridge which can develop very much more than this and have done so. The thermal value of the gas that works the engine, per cubic foot,

at 60 degrees Fahr., ranges from 89 to 106 B.T.U. I don't think we have had any higher than 106. In a test of this engine the indicator card showed $97\frac{1}{2}$ I.H.P.; the electric H.P. put on the switch board was 61·6. The mechanical efficiency was 63·1 per cent. The thermal efficiency per indicated horse power was 26·3 per cent., and for electrical horse power 20·4 per cent. The gas consumption was 108 cubic feet per I.H.P. The engines at Sheepbridge run continuously from Sunday to Saturday, and are effecting a very considerable saving upon the steam plant. We had a good deal of trouble with regard to lubrication at first, but eventually we got over it, and it now runs on about three-fourths of a gallon of oil per 24 hours.

THE CHAIRMAN: We are much indebted to Mr. Hall for reading this valuable paper at such an opportune time, when we are about laying down a very large Mond gas plant in this district. It seems to me that the gas engine is the engine of the future. Whilst it will not meet all the requirements of machinery users, it can be so adapted as to overcome a large number of the objections raised against it. By the aid of friction clutches, for instance, a constant running engine can be utilised for purposes for which it could not otherwise be employed. There are firms in this district (Messrs. Cochrane and Co. for instance) who are leading in the adoption of gas. They have laid down a Mond gas plant, and if other employers in the district will follow their example, either by laying down their own plant or by utilising the power-gas of the Mond Gas Company, that might be a means of keeping the district alive, and enable us to compete with other districts.

MR. HALL: As to the criticism raised with regard to the Hornsby Co.'s estimate of consumption of producer gas. Yes, that figure is certainly too high. I am sorry to appear also to have misunderstood some of the particulars supplied to me by the Industrial Engineering Company, but there is evidently something needing explanation about their figures. For instance, in the analysis of the gas made by their plant you will see in the figures they sent me they mention 13 per cent. of nitrogen. But there is no coal in existence which has so much nitrogen, therefore it is clear that air must have got in; you cannot split up the hydro-carbons into separate gases unless you have an excess of oxygen present at the time. Whether intentionally or not, it is obvious that a certain amount of air must go down into the producer during the downward blow; there is no other way of accounting for the nitrogen there. If they can keep the fuel consumption down to 1lb. of coal per indicated horse power in a 10 H.P. plant, it is indeed a remarkable efficiency, beyond anything I have ever heard of. In the gas producers in which anthracite fuel is used, and which do not receive attention for some hours, the difficulty as to variation is got over by using inside the producer a hopper in the form of an inverted cone, and therefore there is not the amount of variation in the gas which Mr. Hills seems to anticipate. With regard to the starting of the Industrial plant, it is started in a very few minutes.

As to being able to vary the speed of the gas engine by as much as 50 per cent., I know that when I asked for a variation of only 10 per cent. some years ago, I could not get it done. I am glad, therefore, so much progress has apparently been made since then. But still, there are cases in which even greater variation is required, as for instance in mining engines. Now, Mr. Pilkington seems to think that I have taken for purposes of comparison large steam engines and small gas engines; but I may say that this is not the case. I have taken the best possible producer and the best possible gas engine; also the best boiler and the best steam engine. With regard to his observation that you cannot easily get a horse power from a steam engine of 300 H.P. with 3lbs. of slack. I quite admit it. In fact I intimate somewhere in my paper that whilst it is possible, I question whether it is advisable. With regard to gas engines driving rolling mills, no doubt reversing mills could be driven by reversing clutches, but the wear and tear of clutches is very great, and consequently they are not much used. At the same time, I know of one case in Birmingham where a gas engine is driving a rolling mill which is engaged in rolling brass. We have had some very interesting figures from Mr. Pilkington; and I was also glad to hear that the power of gas engines can be varied down to one-seventh.

Mr. RIGBY: It can be done with bituminous, but not with anthracite.

Mr. HALL: I thought it seemed a little extraordinary.

Mr. Pilkington is correct in saying that the most recent determinations make Joule's equivalent 778. I have been accustomed to 772 for so many years that I find it difficult to remember the newer figure, now believed to be more correct.

Mr. Pilkington is mistaken if he thinks I said that gas engines worked by producer gas need not be larger than those driven by illuminating gas. On the contrary, I have said (page 106) that they "require to be 15 to 20 per cent. larger, on account of the large quantity of inert nitrogen contained in the gas." Such gases usually have a heating power of 160 B.T.U. per cubic foot, but the gas made in the Industrial plant is of a quality of 310 B.T.U., and chances to have such a composition that $2\frac{1}{4}$ cubic feet of the gas require for explosion $6\frac{7}{8}$ cubic feet of air, and such a mixture he will find contains just the same heating power as the common mixture of 1 of illuminating gas to 8 of air, usually employed in gas engines. The larger proportion of CH_4 contained in illuminating gas accounts for the difference, these hydrocarbons requiring a larger proportion of air to effect combustion than is necessary in the case of CO.

Mr. H. PARRY: Mr. Hall has given us a very interesting paper. I believe I am expressing what is your feeling in the matter, when I say that we ought to give him our very hearty thanks for the treat he has afforded us to-night. I beg to move a resolution to that effect.

Mr. C. E. Bloomer: I have very great pleasure in seconding the proposition. The paper has been most interesting. As we all know, this is a subject that is very much coming to the front, and if we are to be up-to-date, the gas engine is one of the sources we have to look forward to for our motive power.

The Chairman: I have very much pleasure in supporting it. I know of no abler man in the Midlands as an engineer, and he has rendered very great service to the Institute for some years past.

The resolution was carried by acclamation and suitably acknowleged.

CORRESPONDENCE.

Mr. H. Pilkington: In the discussion on Saturday last, I mentioned reversing mills driven by continuous running engines being reversed by means of clutches. The author appears to have assumed that the old-fashioned style of clutch was referred to; but my reference really meant a modern form of coil clutch, commonly called the Lindsay Coil Clutch, which, although not very much adopted in this country, has been extensively used on the Continent. Krupp has two, one of 1,000 H.P. and the other 800 H.P. Also a steel works at Dusseldorf has two of 4,000 H.P. each. The Fagersta Works in Sweden has a cogging mill fitted with coil clutches which will transmit 5,000 H.P., and I know of a works in Dortmund which is constructing reversing clutches capable of transmitting 8,000 H.P., for a plate mill capable of rolling ship or boiler plates 12 feet wide by 36 feet long, for which the driving power is a turbine of 1,200 H.P. running at 80 revolutions per minute, the mill being geared down to 35 revolutions per minute. My whole point in referring to clutches was, that continuous running gas engines could just as easily work reversing rolling mills by means of these clutches as a turbine could.

Reply by Mr. Hall to Mr. Pilkington's communication :—

Mr. Pilkington's additional communication concerning the coil clutch is very interesting. I have fitted these clutches to cranes, and have found them work most satisfactorily, and was aware that they had been used for rolling mills, but was not aware that they had been employed on so extensive a scale.

Though it is possible to drive a mill with an engine running continuously in one direction, and to reverse the direction of rotation of the rolls, yet this does not afford all the advantages of the mill driven by the ordinary reversing engine, even if the clutches should be free from any objectionable wear and tear. A rolling mill driven by a pair of reversing steam engines starts the rolling gently, and raises the speed to any degree

desired during the course of the run, thus securing the highest speed of rolling possible, without those shocks which are inevitable when the piece has to enter rolls driven by an engine running at one fixed speed, which must be kept down, to avoid the sudden shock of entering the bar in a fast running mill. So great is the advantage of this momentary speed control, that in some cases the single continuous-running engine driving a three-high mill has actually been replaced by ordinary coupled reversing engines, in spite of the fact that such engines were known beforehand to consume more fuel than the single engine they were to replace, the advantage of a gentle grip and a rapid finish being considered of more value than the additional fuel.

Mr. F. J. ROWAN (Glasgow): There are some figures in Mr. Hall's paper which are so extravagant that they can only point to some error in the calculations of those who supplied them to the author. I refer to those on page 104, where it is stated that from a Warwickshire slack, of which the analysis is given, Messrs. Crossley obtain gas of 185 and 200 B.Th.U. (per cubic foot is of course meant) in a producer which is described above.

The calculation of thermal value from the analysis of the gas shows that these figures should be 182·04 and 195·03, but even these are such impossible figures with such plant that I think Messrs. Crossley should have an opportunity of revising them.

No gas producer but one in which the tarry vapours are wholly broken up into permanent gas could possibly produce, from bituminous slack, gas of the value shown; and the statement just following these analyses, viz., that "180 B.Th. U may be regarded as *a fair average gas* to be got from bituminous slack," is also very much over the mark.

140 to 160 B Th.U. is a much more reliable figure for the average value of producer gas from ordinary producers using bituminous slack, judging from the great mass of information which has been made public. I think I have at one time or another come in contact with most of it, and I utterly refuse to believe that any producer, except one with special appliances for passing the heavy hydrocarbons through incandescent carbon, can produce gas of the value shown on page 104.

If, as is stated on page 97, Mr. Dowson can only with care realise a thermal efficiency of 82·7 per cent. when using anthracite, it is not at all likely that a producer using coal with 12·7 per cent. ash and 10·10 per cent. moisture, and worked by an air blast with a comparatively small quantity of steam, and losing tar and oil, is going to show 96 per cent. of efficiency.

Mr. J. RIGBY's reply:—

Mr. Rowan says he utterly refuses to believe that except with special appliances for passing the heavy hydrocarbons through incandescent

carbon such gas can be produced. With all deference to Mr. Rowan's experience as regards producer gas and its application, the fact remains that such gas is, and can be, obtained by us without the special appliances he refers to. He further states that 140 to 160 B T.U is the average figure obtained. That may be so, but he evidently does not take into account the fact that we superheat the mixture of air and steam before entering the producer. That, and the fact that little steam is used with the air in the producer, are some of the reasons for obtaining such excellent gas. He further states that we claim 96 per cent. efficiency of the producer. This is not the case, and if Mr. Rowan had been present at the meeting he would have heard the author in his reading of the paper give from 115,000 to 145,000 cubic feet per ton, according to the quality of the slack used, though it is only fair to Mr. Rowan to note that the former figure, 115,000, was by accident omitted in the advance copy he received. With the Warwickshire slack mentioned, we make with care 120,000 cubic feet per ton, which works out at nearly 87 per cent. efficiency. This is taking the calorific value of the fuel as given in the paper at 11,175 B.T.U. Mr. Rowan also refers to the Dowson results, namely, 82·7 per cent. efficiency when using best anthracite, but we think he must have overlooked the fact that in the Dowson plant the hot gases leaving the producer are cooled atmospherically, and the heat wasted. In our system we utilise this waste heat to superheat the air and steam and to raise steam, which heat is thus carried back to the gas producer in regenerative fashion. It does not seem quite clear how Mr. Rowan has arrived at 96 per cent. efficiency. 145,000 cubic feet of gas at 180 B.T.U. per cubic foot give 26,100,000 B.T.U. per ton of fuel. The fuel value of 2,240 lbs. of fuel, at 11,175 B.T.U. per lb., is only 25,032,000 B.T.U. If he used those figures for his calculation, he seems to have made the error of dividing 25,032,000 by 26,100,000, which happens to come out nearly 0·96, whereas 26,100,000 should have been divided by 25,032,000, giving the absurd efficiency of 104·2 per cent.

Mr. B. H. Thwaite: I sincerely congratulate Mr. Hall. He has written a most instructive paper, and one that covers a field so wide, and bristling with so much matter of a contentious character, that only by a supplement of equivalent length could the many points he raises be adequately analysed.

The historic portion, as far as it refers to the distribution of generator gas from a central supply, is somewhat misleading. Siemens' proposals are *not at all* in line with the one I conceived and published in 1887 and 1888, in which the gas proposed to be supplied, was generated on the coalfield, and the scheme of distribution was as near as practicable on the lines of the method in use for the distribution of the natural gas in the United States. The system to be economical, involves the employment of very high pressures at the generating station or source of supply, 300lbs. to

the square inch being commonly registered. The proposal included the use of pressure regulating and reducing valves as employed in the natural gas service.*

As we know, the mere interest depreciation and maintenance charges, in ordinary retort gas distribution practice, involve a charge of 2d. to 3d. per thousand cubic feet delivered. It is obvious that only by the supply of gas at a considerable pressure would it be economically possible to deliver producer or equivalent low-heating value gas at an acceptable price to the consumer.

The intervention of the success of the method of transmitting electric energy over long distances at high pressure reported to me about 1889, by my friend Mr. Charles Brown (of Basle), destroyed at once the economic rational of the distribution of producer gas at least for power development applications.

But of course, this does not necessarily mean that it would not be found economical to distribute low heating power gas for purely heating purposes and at the high pressures defined, which of course involve the use of a gas that is uncondensable under high pressures.

The gas that is ideal for purely heating or furnace applications is quite distinct from that which is ideal for power development applications—for this latter the ignitability should depend upon physical compression—a gas of 110-120 thermal units per cubic foot will be found perfectly satisfactory (if its hydrogen or hydrocarbon elements do not exceed one fifth of the total combustible proportion of the gas) after compression to six or seven atmospheres.

The author's reference to my own systems of gas generation is both incomplete and misleading. I would refer him to the *Engineer*, volumes for 1892; to the *Electrical Review*, for 1897; and to an excellent treatise *On the Otto Cycle Gas Engine*, by Mr. Norris, M E., for fuller particulars of my different systems and the results of their working operations. The complete cycle utilising the jacket water heat, and the sensible heat of the waste exhaust gases, was patented by me in 1887 and 1888, and described in the *Engineer*, in 1892. The method of recovering the sensible heat of the generator gases for heating the air for supporting combustion in the generators was covered in my patent of 1894. No system of gas generation, except the object is to secure a high proportion of nitrogen as ammonia, such as Dr. Ludwig Mond's, is satisfactory that involves the use of a steam generator, and in my systems I avoid the employment of a steam boiler altogether.

A modification of my reversal process is becoming popular in the

*Vide "Gaseous Fuel: Its Production and Application," by B. H. Thwaite, C.E. Whittaker and Co., London.
Vide "National Review," No. 117, November, 1892.

United States and is now being used in a semi-continuous mill; it is also being adopted in Germany.

The consumption of fuel per I.H.P. hour gross, and including the power energy absorbed in driving fan, is as —

Steam engine consumption coal	..	=	[illegible] lbs.
Producer unwashed slack coal, continuous quality maintenance	..	=	[illegible] lbs.
Ordinary coke neglecting fan	..	=	[illegible] lbs.
Ordinary coke including fan	...	=	[illegible] lbs.

By the complete application of my recuperative methods, these results could be reduced by at least [illegible] per cent. I do not think that sufficient credit is given by Mr. Hall for the high durability of the gas plant compared with a steam power plant. With the exception of the generator per se the gas plant, including holders, will be good for service over a period of [illegible] years—indeed members of my family had until recently a gas holder in service which had been in use for upwards of 50 years. The only care exercised was a periodical application of the tar brush.

There should be no difficulty in starting a high power capacity gas engine. Engines designed by my staff have been started times without number in less than two minutes, and from the cold.

An automatic reversal gear can easily be provided to avoid the necessity of hand reversal.

There is no necessity to run at any particular speed, the range of economy will not be overstepped if the speed is varied between the limits of [illegible] and [illegible] revolutions per minute.

Gas engines are in use on the Continent for driving rolling mills. It must, however, be clearly understood that the astounding development of gas engines in the last five years is entirely due to the discovery of the power value of blast furnace gas, and because this success is so striking it must not be taken that a similar success would follow the use of any generator gas that differed in *chemical* or *thermal character* from this blast furnace gas.

Mr. HALL's reply to Mr. Thwaite's comments:—

I am pleased to see Mr. Thwaite's contribution to the discussion of this subject, and am entirely of his opinion that, owing to the size of the pipes required, it would be, commercially, impossible to distribute producer gas, except for short distances, unless the gas were delivered under considerable pressure. A very little investigation of the question should suffice to satisfy any one on this point. I also agree that the recent great developments in gas engines of large size are due to the use of blast furnace gas, which is more easily used in large engines because it is less liable to premature ignition than richer gases. Naturally the attempts were first made with this gas, because it was

almost a waste product, before making gas on a large scale, expressly for use in gas engines.

I have not drawn any comparisons between the schemes for distributing gas by Mr. Thwaite and Sir William Siemens respectively; I did not refer in any way to the former, and am of Mr. Thwaite's opinion that for distributing power over long distance the electric method is decidedly preferable. All I said as to Siemens' scheme was, that it contemplated distribution over nearly the same district as that selected by the Mond Company in South Staffordshire.

With regard to the remarks on page 105 of my paper, I have no means of referring to Mr. Thwaite's own book which he mentions, but I have referred to the book by Mr. Norris, which Mr. Thwaite commends as "an excellent treatise," and on page 213 is a cut, and on page 214 a description of the Thwaite ("B") gas producing appliance, which consists of two brick-lined cylinders connected near their upper ends, the first filled with slack and the second with coke. The air and steam pass upwards through the side filled with the coal, and then down the second filled with coke. On page 221 we are further told that the consumption was on test 2·01 lbs. per I.H.P., a figure which Mr. Thwaite himself confirms in his own communication. Under these circumstances I am at a loss to understand how Mr. Thwaite can say that my description is "misleading."

My reply to Mr. Pilkington answers Mr. Thwaite's remarks as to starting, reversing, and varying speeds required for rolling or like purposes.

The Sixth Meeting of the Session was held at The Institute, Dudley, on Saturday, the 21st March, 1903.

The President (Mr. Walter Somers, J.P.) presided.

The minutes of the previous meeting were read, adopted, and signed.

Mr. John C. Davies was elected a member of the Institute.

The President then introduced Mr. Axel Sahlin, who delivered a descriptive address, which is embodied in the following paper, on "The Modern Continuous Rolling Mill," illustrated by lantern views of the plates attached to the paper.

THE MODERN CONTINUOUS ROLLING MILL.

By AXEL SAHLIN, Millom, Cumberland.

Those interested in the history and development of the Continuous Rolling Mill are referred to a presidential address on "Some Landmarks in the History of the Rolling Mill," read before the American Society of Mechanical Engineers, in the year 1900, by the retiring President, Mr. Charles H. Morgan. In this most valuable and admirable treatise, the inventions and development of continuous mills are traced and brought down to the date of the address.

It seems that France, America, and England have, in the order named, added their contributions to the solution of a problem which is now, and is still more destined to become, one of paramount importance to the steel manufacturing industry. It is, however, to Great Britain that the honour of the first really workable continuous mill belongs, while America may rightly claim to have developed, completed, and modified the British invention into what we to-day understand as a Modern Continuous Rolling Mill.

The first practical success in continuous mill construction was achieved by the late Mr. Geo. Bedson, of Manchester, of whom Mr. Morgan says—"He first made the mill go." Bedson mills, more or less modified, are yet, I understand, in operation in various places in England. The Bedson rod mill opened the way to the use of heavier billets, that is, longer wire rods, than it had been possible or practicable to roll on the Belgian mills. The English mill was, however, complicated, as it required alternate pairs of rolls to be placed vertically and horizontally. This change in position required two separate systems of gears and made the mill inaccessible. It, therefore, was left for Mr. Morgan to place in one horizontal plane all the gearing and all the rolls of his first mill, which was also the first of the modern type, and which was designed and built by him in 1878, at the works of the Washburn and Moen Manufacturing Company, at Worcester, Mass. In order to give to the billet working pressures at various angles and from different sides, twist guides were introduced between some of the roll stands, by which the metal was turned 90 degrees before entering the following pass.

It is my object in this paper only to deal with these mills as I have found and investigated them during a tour of study and inspection in the United States, in January and February of the current year.

The continuous system of rolling carries with it a limitation, which increases with the lack of skill of the roller. The reduction of the metal

[illegible] mills, is generally caused by the pressure of the rolls [illegible] in order to ensure against overfeed, it is customary in the continuous mill for the rolls to be adjusted so that a certain [illegible] permanently exists in the bar between each pair of rolls. The [illegible] is small, but it may slightly reduce the section of the bar. The [illegible] small [illegible] out of the bar for a couple of feet at the first end [illegible] slightly larger in section than in the intervening part. This is particularly the case in rolling very small sections, which would [illegible] the slightest [illegible]. When rolling larger sections [illegible] the [illegible] of adjusting the rolls for [illegible] is unnecessary. In rolling [illegible] may even have [illegible] instead of [illegible]. Passing between the rolls of course [illegible] slightly small instead of large.

The purely continuous mill as at present designed is therefore principally used in the preparation of products or sections which are afterwards, if necessary, to be finished in separate finishing mills or drawn through dies. Billets and wire rods are to-day the principal products from the continuous mill, but great success has also been achieved in using this simple, automatic process, which renders the [illegible] very small, for the production of smaller finished sections in long lengths. In the United States, cotton ties are largely and most economically produced in purely continuous mills. At the Illinois Steel Company's works at Joliet, Ill., I saw a 10in. continuous mill, which had an average record of over 180 tons per day of $\frac{9}{16}$in. square spike bars of uniform sharp-cornered section and free from end fins. These bars were afterwards manufactured into railroad spikes in the Company's own works.

The best arrangement for rolling a large range of merchant sections (squares, rounds, flats, crosses or light angles) has been found to be a continuous mill, followed by a certain number of stands of finishing mills placed singly or in trains, through which the bar is repeated, and in which it is given its accurate, finished section. Such mills have during the last three years come into extensive use.

The modern continuous mills may be divided into three classes—billet mills, wire rod and cotton tie mills, merchant bar and light angle mills. None of these mills owe their economy or their productive capacity entirely to the roll train itself, but also, and largely to the ingenious accessories, which form, and must form, an important part of such a plant, in order to prepare and take care of the rapidly-finished product.

I. THE CONTINUOUS BILLET MILL.

The continuous billet mill, Fig. 1, consists of from 6 to 12 pairs of rolls placed tandem, but close to each other. Between every other pair of rolls, twist guides serve to turn the advancing steel an angle

of 90 degrees. The rolls are driven through spindles and steel pinions by a series of bevel gears so proportioned that the speed of each succeeding pair of rolls will take up the elongation of the bar of metal produced by the preceding pass. All of these gears are driven from one shaft directly coupled to the engine (which, running 55 revolutions, indicates about 2,000 H.P. when taking billets from the blooming mill without reheating), and parallel with the axis of the mill. The practice mainly in use in America is to furnish the steel to the soaking pits of the blooming mill in ingots weighing from 2 tons to 3½ tons. The soaking pits are of the ordinary Pittsburg type, each pit having four holes, each hole holding four ingots. The ingot is broken down on a reversing blooming mill into a billet 4in. by 6in., or 3½in. by 7in. in section. In passing from the mill, the forward or top end of this billet is cut off in a hydraulic shear, and the billet is then in its entirety, without reheating, advanced to the continuous mill. It enters this at a relatively slow speed. It leaves the last pass as a billet 1¼in. square, 600 to 1,000 feet long, running with a velocity of 500 feet per minute.

No machinery previously devised in the form of shears or saws would have been able to cut this bar while in motion, or to cope with the tonnage produced.

It remained for the "Flying Shear," invented by Mr. V. E. Edwards, of Worcester, Mass., to solve this problem. This shear is shown by Fig. 2. It consists in principle of an upright frame pivoted at its lower end, and carrying near the top the lower shear knife. Fastened to a slightly inclined pair of links, also pivoted at their lower end and to the same bedplate as the upright frame, is the upper shear knife, which is hinged to a crosshead, guided in a groove in the first-mentioned vertical frame. If this vertical frame is pulled forward, the inclined links will drag the upper shear knife downward until it engages with the lower knife, when a bar advancing between the shear knives would immediately be cut. The shear then stops, having reached the end of its stroke, but the on-coming bar continues its uninterrupted motion and quietly pushes the hinged upper knife out of the way, thus allowing the shear to slowly return to its first position. In order to make this shear successful, it was necessary to design a contrivance which would at the proper moment drive the vertical frame forward with the same velocity as that of the advancing bar, and also to find means for promptly returning the shear to its original position. This double object was accomplished by special steam or hydraulic cylinders controlled by a trigger or electric contact. The action of the cylinder is regulated with such accuracy that the time from the moment the bar strikes the trigger or electric contact until the cut has been completed may be controlled and known to within two 100ths of one second, and the length of the cut billets to within 1in. Even this slight variation is largely due to varying temperatures of the

steel and to uneven speed of engine. Indicator diagrams have been taken which show, with unquestioned accuracy, the time occupied for each part of the movement of this "cut in transit."

The Flying Shear has made it possible to cut billets to any length from 12ft. upwards, and to handle a steel bar several hundred feet long within a space a few feet wide, and only about 10ft. longer than the billet which is being cut from it. After dropping from the shear, the billets advance on rollers to the assembling or "skew roll" table. In order to arrange this stream of billets into a neat bunch, preparatory to pushing them out on to the hot bed, the driven rollers of the table are set at an angle. The billets are, therefore, driven forward against an end stop, and broadside against a side straight edge, thus automatically and neatly grouping themselves side by side. An 8,000lb. ingot gives 35 1¼in. by 30ft. billets, and makes a bunch about five feet wide. Between the consecutive billets there is, of course, no delay, but between the consecutive ingots there is generally a clearance of, say, 15 seconds. This allows time for pushing the bunch out on to the cooling bed by means of the side straight edge, which is driven from a motor by a pair of wire ropes. At the end of the cooling bed the cold billets are dropped into "U" shaped frames placed on a weigh bridge. Two chain slings are placed around the billets, which are handled in units of from 10 to 15 tons by an overhead crane, and loaded on cars for shipment or carried to the charging table of the furnaces of the finishing mills, as the case may require. Fig. 3.

The billet mill consists, generally, of rolls of from 14in. to 16in. diameter. The first rolls are made somewhat smaller in diameter than the later ones, so that when the roll is worn out it may be re-dressed and placed in the second pass ahead of the one in which it has previously been serving. A considerable economy in the consumption of rolls, and in roll turning, is hereby effected. The roll housings, which rest on one common shoe or bedplate, are made of strong charcoal iron. The adjustment of the rolls is made by means of wedges, not by screws. The steel pinions are run in oil in hermetically closed housings. A mill of nine stands of rolls will reduce from 900 to 1,800 tons of 4in. by 6in. blooms into 1¼in. billets in 24 hours. Including every man in any way connected with the mill, the number of workmen required is ten per shift, out of whom only the roller and engine driver need to be specially trained for their positions.

Owing to lightness of parts, low speed, continuity of stresses, and freedom from shocks, the wear and tear in this class of mills is very light. Repair charges are low. The continuous system is, therefore, rapidly becoming a favourite means for production of the smaller billets now largely taking the place of the 4in. by 4in. section hitherto used as the commercial billet in the United States, and rolling mill men are again re-

turning to the smaller sizes of billets, which we in England have never ceased to recognise as the proper raw material from which to finish steel of small sections. Some of the advantages of the small section billet are :—

(1) Economy in handling.
(2) Facility for inspection.
(3) Economy in reheating.
(4) Uniformity of heat conditions, making it practicable to roll long lengths.
(5) Economy in rolling.

The cost of a continuous 14in. billet mill, with feed roller table, shears, delivery roller table, hot bed, crane, gearing, 2,000 h.p. compound condensing engine, boilers, pumps, and building may be estimated at from £25,000 to £50,000, depending on location, completeness of appliances, and time of construction.

A continuous billet mill will make a yearly average of 98 per cent. of cut billets, from 4in. by 6in. blooms. In the United States, the cost of rolling these small billets may be estimated from 1s. 3d. to 1s. 6d. per ton, including allowance for interest and depreciation. The fact that such firms as the Carnegie Steel Co., Jones and Laughlin Steel Co., National Steel Co., Republic Iron and Steel Co., and Dominion Iron and Steel Co., and many others have installed continuous mills of large capacity is the best proof of their commercial and technical success.

II.—THE CONTINUOUS WIRE ROD AND COTTON TIE MILLS.

A.—*Wire Rod Mills.*

The Belgian mill, as compared with continuous mills of these later years, has only one advantage, as far as I can judge, that of low first cost of installation. The drawbacks, on the other hand, are (*a*) the impossibility of rolling long lengths of rods ; (*b*) extra use of severe manual labour ; (*c*) excessive consumption of power, that is, steam fuel ; (*d*) variable heat treatment of steel, the first and last ends of the rod leaving the finishing rolls at widely different temperatures, causing a variation in hardness or "temper," and also in dimensions, both of which irregularities are positively felt in wire-drawing departments, where continuous rolled and loop rolled rods are utilised side by side.

The only wholly continuous rod mill on the market in the United States is constructed by the Morgan Construction Company, and is the outcome of 34 years of unceasing study, observation, and improvement. The mill consists of two trains of continuous rolls. The roughing train receives the 1¾in. square billet directly from the heating furnace, and reduces it in six passes of 10in. or 11in. rolls to a section of ½in. square. The forward end of this bar is cropped in a flying shear after leaving the roughing train, and passes through a tube-shaped guide into the first pass of the eight continuous stands of 10in. finishing rolls. The mill may roll

one single wire rod at a time or two wire rods side by side. The action should be continuous, a fresh billet entering the mill within 6in. of the rear end of the previous billet. The housings are placed on continuous bed plates. The adjustment of the rolls is made by wedges. The rolls for each pass are gradually somewhat increased in diameter towards the finishing pass, the rolls for which are generally turned with 24 grooves, all of which can be used, one after the other, until the whole surface of the roll is worn out. Not until then is it necessary to change rolls. The worn out finishing roll may be re-dressed and used in the third pass from the last, afterwards in the fifth pass, and then in the seventh. In the same way, the rolls in the roughing train may from time to time be re-turned and used in the previous roughing passes. The high-speed rolls are driven through spindles from machine-cut steel pinions running in oil in hermetically closed housings. Both trains are driven by one engine, which should have a capacity of 1,000 I.H.P. for one strand, or 1,600 I.H.P. for double strands. The pinions of the roughing train are turned by direct gearing from the engine shaft, while the finishing train is usually driven by two leather belts, one riding on top of the other. Each belt drives two pulleys, and each pulley, by a nest of cylindrical gears, drives two stands of rolls.

The billets arrive from the billet mill in bundles of from ten to fifteen tons, held together by two sling chains. They measure, as a rule, 30ft. in length, with a section of 1¾in. square. The weight of each billet should for best economy be not less than 300 lbs.

The billets are automatically fed into a Morgan Continuous Furnace having a suspended roof. The furnace, Figs. 4 and 5, is an integral and necessary part of the rod mill. Its bed usually measures 32ft. by 20ft. It slopes towards the hot, or discharging end, at a pitch of 2ins. to the foot. The upper part of the furnace bed consists of water cooled pipes or "skids" on which the billets rest. The central part of the furnace bed is formed with fire-brick; the lower, the hottest, part is paved with magnesite brick. The roof is turned in three arches, each having about 7ft. span. The hanging skew backs for these arches are supported by 2in. double extra heavy pipes, through which water is flowing. These pipes are suspended from steel girders resting on the furnace walls. Special skew-back bricks, with semi-circular recesses, are placed over the pipe, and against the sloping faces of these bricks the roof arches rest. This construction has been in use since 1896, has proved very durable and satisfactory, and has a great advantage where used over a large and wide bed, as it makes it possible for the roof to be brought as closely as desired to the bed, thus securing uniform heating of the 30ft. billets. Above the arched and refractory roof, a hollow space is formed by a second roof of corrugated iron, covered with sand. At the lower end of the furnace, air is admitted into this space, whence it is drawn by an exhaust fan. After passing through this fan, the air is returned to the space under the

bed of the furnace. Here it passes through a stove built of fire-clay pipes, around which the products of combustion from the furnace play on their way to the smoke stack. The air is finally led under the bottom of the furnace into the fourteen air ports; each port being about 4½in. square, and controlled by its own valve. The gas enters through fourteen gas ports, 9in. by 13½in. in size, each controlled by its independent, water-cooled slide valve. The gas is delivered into these ports through short flues directly from the adjacent gas producers, which will be described later.

The draught is entirely regulated by the exhaust fan. The smoke stack is simply a flue for conveying the products of combustion out of the building. The billet is delivered at the upper corner of the furnace on rollers. At this point it is gripped beteen two pinching feed rollers, which are placed flush with the inside of the furnace wall. These may be driven electrically or by belting, When the billet has been carried through these rollers, it is fairly within the furnace. A steam cylinder fastened to the furnace binding on the upper, cold side of the furnace, turns a longitudinal shaft which is armed with five levers working push bars which enter into the interior of the furnace. By raising the piston of this steam cylinder, the push bars will be made to advance, pushing the billet forward about 3 inches. A new cold billet can now be entered between the pinching feed rollers and run into the furnace. The two are then advanced another step by the pushing device. In this manner the furnace bottom is gradually covered by one continuous layer of 1¾in. billets. As they advance, these billets come into zones of higher temperature and are gradually and uniformly heated until they arrive at the bottom, or hot, end of the furnace, thoroughly soaked and ready for rolling. The rod mill furnace contains about 120 billets, and can, without forcing, deliver 100 heated billets per hour. As long as the billets arrive at the mill fairly straight, the heating process is nearly automatic, one man feeding the furnace, another discharging the billets into the mill. The heater controls both furnace and gas producers. The working of the latter is indicated by gauges fastened to the furnace binding, close to the gas and air valves. Close to these gauges are valves regulating the steam pressure used on the producers.

The delivery of the billet from the furnace into the roughing rolls is effected by a second pair of driven pinching rolls. Between these is entered a push bar, the forward end of which is placed against the rear end of the billet. By pressing the rolls together against the push bar, the drawer forces the hot billet forward through a small door directly into the first pass of the mill.

The Morgan Gas Producers, Fig. 5, are built in two sizes, 8ft. and 10ft. in diameter. Their design was prompted by the absolute importance of supplying for the continuous furnace a gas uniform

in composition, temperature, and quantity. In the ordinary producer, a quantity of coal is periodically dropped in a pile into the producer. As this coal is being heated, the light hydro-carbons and water contained in it are quickly expelled in a flow of rich but cold gas. These products having departed, the percentage of carbonic oxide and acid, which are the products of combustion of the carbon in the coal, greatly increase in the gas, which, therefore, entirely changes its character and composition within a few minutes.

To obtain the necessary uniformity, a special rotating feed device has been designed, which, driven from an overhead countershaft, automatically discharges and spreads a certain. constant quantity of coal over the entire surface of the producer. This feed can be adjusted to run faster or slower without altering the regularity and continuity and distribution of the feed. It has further been found necessary to abandon the square form of hearth, still a bad feature in many favourite designs of producer, and to adopt throughout a circular section, in the centre of which the mixture of air and steam is introduced through an inverted tuyere.

The steam pressure usually varies from 6lbs. to 10lbs. per square inch, and is under full control of the heater in charge of the furnace. The gas man's responsibility is limited to keeping his fuel bed and ashes of proper depth.

The thickness of the layer of ash and coal in the producer has a great influence on the composition of the gas. The best effect is obtained when ashes reach a line 3ft. or thereabouts above the central tuyere, and are covered with a 2ft. 6in. layer of coal in various stages of combustion. A number of inspection holes piercing the shell and lining are, therefore, arranged at intervals around the producer at a level 3ft. above the mouth of the tuyere, or in the plane where the coal ought to be completely consumed. By periodically removing the ashes, so that the bottom layer of coal reaches the level of the inspection holes, the desired quantity of ash may be left in the producer. The heated ashes,through which the mixture of air and steam must pass before coming in contact with the fuel, act as a sort of continuous regenerator, saving the heat left in the ash, at the same time as the action of the steam serves to disintegrate the clinkers which, when bad coal is used, so greatly embarrass the operation of our ordinary producers. The average composition of the gas delivered by the Morgan Producer is, as follows :—

O	...	·4 per cent.
CO	...	24·5 " "
CO_2	...	3·7 " "
H	...	17·8 " "
N	...	46·8 " "
CH_4	...	3·9 " "
C_2H_4	...	3·2 " "

It is desirable that the gas should enter the furnace as hot as possible ; therefore the producers are placed as closely as practicable to the heating furnace.

As a definite record of the performance of the combined Morgan Producer and Furnace, it may be stated that the average quantity of fuel used for heating one ton of cold 1¾in. billets for the rod mill at Grand Crossing Tack Company's works at South Chicago, during the year 1902, was less than 150lbs. The coal used was of the average Illinois quality, which in ordinary producers gives a great deal of trouble from the accumulation of clinkers. I examined the ash pile at these works and found no clinker larger than a man's fist.

When the drawer, by means of his pinching rolls and the square pushing bar gripped between them, has pushed the hot billet through the delivery door, it enters directly through a "V" shaped guide into the first pass of the roughing train, which is placed close up against the wall of the furnace. (Fig. 7.) The billet advances through the following passes, and through alternately straight or twisted guides at an increasing velocity, until it leaves the 6th pass in the form of a ½in. square bar, which is cropped in a flying shear, so that the bar will invariably present a clean entering end at the first of the eight finishing passes through which it successively and automatically advances. The velocity of the rod leaving the mill is about 2,000 ft. per minute. The time required for passing the first end of the billet through the fourteen passes is only about fifteen seconds, during which the rapid reduction from 1¾in. square to No. 5 wire rod has taken place. The amount of mechanical work so rapidly expended on the small quantity of steel has the effect of heating the same nearly as much as the flood of cooling water on the rolls lowers its temperature, so that the rod leaves the mill at a heat only slightly less than that at which the billet entered the first pass. In the furnace the heating has been so gentle, and the atmosphere so reducing, that no slag is formed and very little oxidation has taken place. Some scales which cover the billet when they reach the factory will be found lying dry on the magnesite brick at the lower end of the furnace, whence they may be periodically scraped off and removed. In passing through the mill, the rod is for the greater part of the time running through guides, or under water with which the rolls are being sprayed. The oxidation during the time of rolling is, therefore, brought down to a minimum. To protect the rod from oxidation after leaving the mill, it is led through a pipe some 50ft. long through which water is continually flowing. (Fig. 8.) In this, the rod is rapidly cooled, without being exposed to the oxygen of the atmosphere, until its temperature is reduced below the point where oxidation takes place.

The guiding pipe is arranged as a switch which may convey the rod to either of two Automatic Morgan Laying Reels. This ingenious machine is shown by Fig. 9. It consists of a bedplate sloping at an angle of about

[illegible]

[illegible] by the rolling mill.

[illegible] made during [illegible] pass through the mill. [illegible] The time from the moment [illegible] begins [illegible] of the billet are therefore [illegible] at the time when the [illegible] in the furnace. [illegible] of the billet are either in the furnace [illegible] need destroy more than one third of [illegible] happen in any mill, a mishap should occur during the rolling, the roller immediately drops a chisel-like shear attached to the housings on to the billet in front of the first roughing pass, and at the same time the [illegible] billet is instantly cut by the flying shear between the two trains. The portion of the billet in the mill is, therefore, run out partly as [illegible] square rod, which is easily handled and

may be merchantable, and partly No. 5 wire rod. The remaining portion of the billet is brought back into the furnace, and is ready to be rolled when the cause of the mishap has been removed.

It has been found in practice that the uniform heat treatment made possible by the continuous rolling keeps the rods considerably softer than those rolled on Belgian mills, where the first end is run out hot, while the last end is finished at the lowest practicable temperature. This limits the length of rod produced by the Belgian mill. In the Continuous mill, on the other hand, there is no technical difficulty in rolling rods of any length; but the 300lb. billet has been found a practical size and is, therefore, at present considered as a standard.

Wire rods are a half-finished product. They are seldom used as such, but constitute the raw material for wire. What is required of the rod mill is, therefore, to produce a rod which lends itself for wire drawing without unduly wearing the dies. The Continuous mill in which each pass is independent, and which may be watched and adjusted during the process of rolling, lends itself admirably to the production of wire rods.

Irregularity in section may in any mill be due to three causes:—

(1) Irregular heating, due to the shortcomings of the heater.

(2) Irregular rolling, due to incompetence of the roller.

(3) Faulty devices and machinery.

The first and second of these are local causes, the responsibility for which devolves on the management. The third defect has, in the Continuous mill, been as much as possible eliminated by nearly perfect design and workmanship of the mill, and by well-built and practical devices for adjustment and control. If, however, a certain irregularity should occur in a Continuous mill, the injurious effect of the same is largely eliminated by the action of the laying reel. For every time the radial arm revolves, the rod must of necessity be twisted one turn. The irregularities are, therefore, distributed around the surface of the rod as a slow spiral. Instead of wearing the die at one side only, the wear will, therefore, be distributed regularly around the entire circumference. It has been found possible to draw a No. 5 rod rolled by the Continuous process two gauges finer, without annealing, than a similar rod rolled in ordinary Belgian mills.

The Continuous rod mill has an average capacity of 160 tons of No. 5 rods per 24 hours, when running one rod at a time. If desired, two rods may be rolled simultaneously without other change in the mill than an increase in the number of reels, engine and boiler power.

At the Sharon Steel Company's Works, two Continuous rod mills, placed side by side, produce, when regularly supplied with steel, over 500 tons of rods per day.

In labour, the mill is strikingly economical. The total force employed for a one strand rod mill, that is, for producing 160 tons per 24 hours, is :—

Occupation	Day.	Number of Men. Night.	24 Hours
Roller ...	1	...	1
Roller's Assistant ...	...	1	1
Heater ...	1	1	2
Heater's Assistant...	1	1	2
Charger ...	1	1	2
Charger's Assistant	1	1	2
Feeder ...	1	1	2
Rougher ...	1	1	2
Shear Boy ...	1	1	2
Finisher ...	1	1	2
Rod Pipe Switch Boy	1	1	2
Conveyor Men ...	2	2	4
Ash and Coal Wheeler	1	1	2
Engineer ...	1	1	2
Oiler ...	1	1	2
Scrapman and Sweeper	1	1	2
Scrap Boy, cuts finned ends	1	1	2
Gas Man ...	1	1	2
Gas Coal and Ash Wheeler	$\frac{1}{2}$	$\frac{1}{2}$	1
Handy Man ...	$\frac{1}{2}$	$\frac{1}{2}$	1
Millwright ...	1	...	1
Roll Turner ...	1	...	1
Fireman ...	2	2	4
Water Tender ...	1	1	2
Total men and boys	24	22	46

Of those employed on the mill, only two—the heater and roller—require to be skilled men. Many of the other positions may to advantage be filled by boys. It is seemingly a paradox, that the more work the mill turns out, that is, the more regularly it operates, the less work there is to be done. For that reason, the men are thoroughly in favour of keeping the mills in good condition and of watching all details.

The roll turning for a Continuous mill producing 160 tons per day is performed by one man working single turn. The entire equipment required consists of one roll lathe proper, and one machine lathe for dressing roll necks.

Costs and economies are local questions, depending on price of fuel, price of labour, cost of steel billets, and, not the least, skill, intelligence and attention of operators, and management. The Continuous rod mill will, with good stock, produce close to 97 per cent. of rods from $1\frac{3}{4}$in. billets.

The entire modern rod mill plant is contained in a building 75 to 80ft. wide and 200 to 220ft. long. (Fig. 6.) At the upper end of this building is placed the billet storage. Below this follows the Continuous furnace with its accessories. The gas producers are often placed under a separate shed, built alongside the mill building and adjacent to the furnace. At the lower side of the furnace follows the roughing train, flying shear, and finishing train. About 50ft. away from the finishing pass, near the lower end of the building, are located the reels and the rod conveyor, the far end of which extends outside of the building into the inspection yard or cleaning house. Opposite the train is placed the gearing, belt drive and engine, together with pumps, air compressor, condenser, and feed water heater. At the lower end of the building opposite the reels, is placed the boiler plant, which generally consists of 800 nominal h.p. of water tube or cylindrical return flue boilers. The billet storage is sometimes covered by a light travelling crane. Over the mill and reels is suspended a small pneumatic crane of sufficient power to lift two rolls.

The cost of a complete plant in the United States may vary, according to location, completeness and time of construction from £30,000 to £40,000. It has in every case proved a sound and very profitable investment.

B.—HOOP MILL.

The wire rod train may be used for rolling hoops and cotton ties. The latter are ⅞in. wide by No. 19 wire gauge thick. They are rolled from the ordinary 1¾in. billet. Only four stands of the finishing train are used. When the band leaves the last of these four stands it is still at a high temperature, and as delicate as wet paper. It is now run through an oscillating distributor, which deposits the slender band in regular loops or waves on a slowly moving conveyor or apron, shown by Fig. 12, on which the loops are standing, so that the broad sides of the cotton tie may cool without contact with other metal. This treatment ensures the beautiful, glossy blue oxide finish, which is considered desirable, especially for hoop. When the band has slightly cooled, it is wound up into solid coils, which are placed on a reel and fed through a continuous revolving shear, where they are cut into required lengths of about 11ft. 6in. if cotton tie, or any desired shorter lengths for hoops. A number of ties are then packed into a bundle and buckled together by means of clamps made from scrap tie. Cotton tie bundles are then dipped into a vat, coated with a tar composition, and leave the mill building ready for shipment.

I pass this form of mill with a brief mention, chiefly because England is not a cotton producing country, and because we could hardly expect to compete with the protected hoop and tie mills in America in furnishing this product to the planters of the South. The mill is, therefore, of little direct interest to us.

C.—OTHER USES FOR THE STANDARD CONTINUOUS WIRE ROD MILL.

These mills have successfully produced small rounds and squares in merchantable sizes. Thus, a rod mill at the Joliet Works of the Illinois Steel Co. is regularly rolling spike bars, which are converted into railroad spikes. The last four stands of the finishing train are for this purpose removed and replaced by a flying shear and a hot bed, on which the spike bars are assembled, and whence they are conveyed to the adjacent cooling bed.

THE MERCHANT MILL.

The great waste of material in the manufacture of merchant bars rolled on ordinary three-high rolling mills, and in short lengths, has, during the last three years, caused the construction in the United States of special merchant mills, in which bars are rolled in long lenths and cut up to fill orders or stored entire, so that small orders of standard sections can be cut immediately, and shipped from the stock on hand, without unnecessary waste of good and ready material in short bars or crop ends.

The first of these mills was installed at the works of Messrs. Jones and Laughlins, Ltd., of Pittsburgh. Later, other makers have built similar mills, and the greatest perfection in plant has finally been reached in the magnificent merchant bar mills at the Duquesne Works of the Carnegie Steel Co. An idea of the mill will best be conveyed by a description of this plant.

The two mills, Figs. 13 and 14 (10in. and 13in.), are contained in one steel building 800 feet long, with a single span of 200 feet. Beyond, and at one end of this building, is placed a boiler house covering twelve Babcock and Wilcox boilers, with a combined capacity of 3,000 H.P. The boilers are fitted with coal pockets, elevators and distributors, mechanical stokers and ash conveyors, and the whole is a good specimen of an up-to-date boiler plant.

The 10in. mill is used for sections from $\frac{3}{8}$in. up to $\frac{7}{8}$in. squares or rounds, and equivalents in flats. The larger 13in. mill will roll rounds up to $2\frac{1}{16}$in. squares and equivalents, and has also successfully rolled 2in. by 2in., $2\frac{1}{2}$in. by $2\frac{1}{2}$in., and 3in. by 3in. angles, from $\frac{1}{8}$in. to $\frac{3}{8}$in. in thickness.

THE 10-INCH MERCHANT MILL.

This mill is fed with $1\frac{1}{2}$in., $1\frac{3}{4}$in., or 2in. square billets, in 30ft. lengths; the size used depending on the section of the finished bar. They are transported from the billet department, located at a distance of nearly one half-mile from the bar mills, to the billet storage, which runs the entire width of the building, and is commanded by an overhead travelling crane. The billets are fed into a Morgan Continuous Furnace of the ordinary size, and leave this furnace to pass through a roughing train of four pairs of continuous rolls. The bar is then run through six passes of a six-speed finishing train, of an entirely novel construction. It consists

of six stands of two-high "bull heads," each pair of rolls having its own pair of pinions. They are driven in pairs from three jack shafts running at different speeds. The jack shaft drives the nearest pair of pinions and rolls through the upper pinion. The nearest upper roll connects with the bottom pinion of the second pair. This construction permits of the first rolls on each shaft being made as much smaller than the second pair as may be desired. The object aimed at is construction of a mill in which, under average conditions, each pass is operative approximately the same number of seconds. In other words, the action of the mill is such that if the billet leaves the furnace equally heated, each foot of its entire length will receive almost exactly the same amount of cooling between the furnace and the finishing pass. The heater's orders are to so adjust his furnace by means of the fourteen gas and air valves, that the temperature at the finishing pass shall be uniform. Thus the section of the finished bar is kept uniform from end to end, instead of the last end being larger than the first, as is so common in ordinary bar mills. The sections being frequently changed, automatic repeaters are not advisable. One man is placed at each of the six bull-head passes to enter the bar. The mill is run by a 1,200 H.P. compound condensing engine. The roughing rolls are driven by spur gears, the finishing trains by belts.

On leaving the finishing pass, the bar runs through a pipe to a pair of pinching feed rollers which carry it to the top of an Edwards' automatic gravity cooling bed. This bed is shown by Fig. 16. The top of the bed, along which the newly-rolled bar travels. is fitted with conical rollers, about 10in. diameter at the base and 12in. long. Their axes are placed at such an incline that the top side is horizontal. These rollers are placed 5ft. apart along the 450ft. long cooling bed. The shafts or spindles on which they revolve are pivoted, so that they may be pointed about 5 degrees away from the mill, or the same angle towards the mill. The rollers are supported on, and driven by, an endless electrically operated $\frac{5}{8}$in. wire rope, which passes under them near their base, and is in turn supported by intermediate carrying sheaves. If the conical rollers are pointed away from the mill, the bar which is being run out immediately works towards the base of the rollers. If, on the other hand, the rollers are pointed towards the mill, the bar will leave the base and travel towards the point of rollers. On reaching a point about 2½in. from the apex of the cones, the bar slips over an off-set in the surface of the same, and once outside this off-set, it cannot return again towards the base, however the rollers may be pointed.

The slope of the cooling bed is formed of cast-iron escapement bars, or ladders, resting, top and bottom, in sockets or open bearings. These bars are cast with horns, or prongs, placed alternately at 150 degrees angle, a distance of 3in. from one another. By an arm extending downward from the cast-iron bar in a direction opposite to the line bisecting the angle between the prongs, the escapement bar may be rocked forward and back

through an angle of 40 degrees. In one extreme position the right hand prongs extend above the plane of the bed; in the other extreme position, the left hand arms protrude. These escapement bars are placed at a distance of 21in. centre to centre along the entire length of the 450ft. cooling bed. In the spaces between each ladder are placed two plain rails in such position that all the supports, whether plain or pronged, will form one inclined plane down which the bars will travel while being cooled. At the upper end of each ladder, a long wing-like projection extends backward so far, that a bar resting on the pointed rollers between the off-set and the apex is within reach of these wings. All the ladders are moved forward and back simultaneously by one wire rope, clamped to each rocker arm and worked by a steam cylinder. By turning the ladders so that the wings which are pointing away from the mill are lifted above the plane of the cooling bed, the bar is lifted off the rollers and slid on to the first or top prongs of the ladders. If the piston in the cylinder makes a second stroke, reversing ladders, this same bar will drop to the second line of prongs. Another reversal will bring it into the third line, and so on until the bar has reached the end of the ladder and is delivered on to horizontal sliding bars at the foot of the cooling bed. If a new bar is delivered on to the conical rollers, before each reversal of the ladders, every line of prongs will be made to carry a bar and the gravity bed will be kept filled with gradually cooling steel. As soon as a batch of from eight to twenty bars have been gathered on to the assembling platform at the foot of the bed, they are pushed on to the adjacent delivery rollers to the shear by a number of horizontal push bars, sliding on to the rails which support the rolled bars, and actuated by levers keyed to one shaft which runs the entire length of the cooling bed, and which is oscillated by a steam cylinder. The delivery rollers convey the entire batch of bars to the shears, where the first end is cut off. The bars are then run up against the adjustable stop behind the shears and simultaneously cut into lengths as specified. As each batch is cut, it is pushed on to the weighbridge, Fig. 17, which supports "U" shaped cast-iron cradles into which the cut bars are dropped. Two chain slings are placed around the bundle of bars, which is lifted by an electric crane. If for immediate shipment, two light hoops of round steel are twisted round the bars while they are hanging in the chains. They are then placed on railway cars, the chain slings are detached, and the bundle, which may weigh fifteen tons, is ready to leave the mill. I have frequently seen an entire fifty-ton car load made up of three bundles of merchant bar. (Fig. 2?.)

The 10in. mill described above, rolled in January, 1903, in twenty-four hours, 433 gross tons of ¾in. round rivet bars.

The number of men employed per twenty-four hours, for operating this mill, as well as the 13in. mill, which forms part of the plant, is given below:—

MEN ON CARNEGIE DOUBLE STORAGE MILLS PER SHIFT.

	10in. Mill.	13in. Mill.
Stock Man	½	½
Billet crane Boy	½	½
„ „ Chain Men	1	1
Furnace Charger	1	1
„ Helper	2	2
Furnace Heater	1	1
„ Helper	1	1
Mill Feeder	1	1
Rougher	1	1
Roller	1	1
„ Helper	1	1
Finishers	6	6
Spell Hands	2	2
Helpers	...	2
Scrap Men	2	2
Mill crane Boy	½	½
Cooling bed	4	4
Inspector	1	1
Shear Men	1	1
„ Helper	2	2
Shipping crane	½	½
„ chain Men	1	1
Electrician	½	½
Millwright	½	½
„ Helpers	1	1
Engineers	½	½
„ Helper	½	½
„ Greaser	½	½
Mill Greaser	½	½
Firemen	½	½
Coal Machine	½	½
Water Tender	½	½
Ash Machine	½	½
Bundlers	2	2
Total Men and Boys per 24 hours	39	41

THE 13-INCH MERCHANT MILL.—Fig. 15.

For this mill, 30ft. billets, from 2½in. up to 4in. square, are used. They are heated in a standard Morgan Continuous Furnace and passed through a Continuous Roughing Mill of four passes. Thence this bar travels through curved repeater guides placed at different levels in the floor, turning angles of 180 degrees, and entering consecutively and automatically into the six passes of the finishing train, which is of novel

design. It consists of a train of three stands of two-high "bull-heads," driven by one stand of pinions, beyond which, and running in the opposite direction, are three other stands of two-high "bull-heads" with their stand of pinions. Automatic repeaters are used on both sides of the mill. The Morgan Merchant Mills offer, to the best of my knowledge, the first and only successful arrangement of such automatic repeaters. The secret of their success lies in the spread-out arrangement of the roll stands, which makes it possible to give extra large radii to the repeater grooves.

The bar leaves this train to pass through a pipe guide, which, with the aid of pinching feed rollers, delivers it on top of a cooling bed similar to, though somewhat heavier than, that for the 10in. mill described above. The processes of cooling, gathering, shearing, bundling and shipping the bars are the same as those described for the 10in. mill. The mill is driven by a 1,200 H.P. compound condensing engine, the roughing train by gearing, the finishing passes by belt drive.

The capacity of the mill is from 400 to 600 tons per twenty-four hours.

STORAGE SYSTEM.—Fig. 18.

During the year that these Carnegie Mills have been in operation, the demand for all steel products has been so enormous in the United States that there has never been an opportunity to accumulate a stock of merchant bars. Orders have always been ahead of the producing capacity. The bar storage has, therefore, not yet been completed.

The description which I give below of this system, which, especially for Great Britain, where orders are generally received for small quantities of bars of varying lengths and different sections, should be most interesting and important, refers to the arrangement in the mills of Jones and Laughlin's, Ltd., Pittsburgh, Pa. The cooling beds in this plant are 300ft. long for the 13in., and 350ft. long for the 10in. mill. The floor space between the mills is taken up by pockets formed by lines of "U" shaped stands spaced about 5ft. centre to centre, and extending the entire length of the cooling beds. These stands are formed by double bars of 3½in. by ¾in. steel, and are about 5ft. high. They are coupled and braced by 3in. by 3in. angles placed "A" fashion over the top of the "U's."

Over these pockets and over the delivery rollers to the shear runs a 350ft. long broadside crane. The body of this crane consists of two 10in. channels, held together by distance pieces, and spliced to a length of 350ft. This girder is suspended from wheels running on the channels which form the bottom chords of the roof trusses of the building. A shaft parallel with the crane, cooling beds and pockets, carries a number of sheaves, over which pass endless wire ropes attached to the crane. The shaft is driven by an electric motor. By nicely adjusting the ropes, the

flexible crane, 350ft. long, can be moved from one side of the building tc the other, while kept in alignment to within 1in. of a straight line Under the crane body is suspended a lighter girder of 5in. channels tied together by distance pieces and splice plates. This is carried by chains spaced about 10ft., and running over sheaves resting on the main frame of the crane. The upper ends of all these chains are bolted to one longitudinal bar, which may be moved forward or back by a pneumatic cylinder. When the bar is moved backward, the lower 5in. channel frame is lifted. When the bar is advanced, it is lowered. The stroke is about 6ft., or sufficient for lowering the 5in. girder almost to the bottom of the pockets. Spaced about 5ft. apart, and suspended from this lower frame, are hooks which may be simultaneously opened or closed by an endless wire rope, worked by a pneumatic cylinder. An operating platform is placed at the middle of the crane, whence the transverse motion, the hoisting, and the opening and closing of the hooks can be directed by one man. When it is intended to store a quantity of bars being rolled, the crane is placed over the bars gathered on the delivery rollers to the shears. The hooks of the lower frame are opened. The frame is lowered over the bars until these are well within the hooks. The hooks are now closed under them, and the lower frame carrying the bars is raised, until the latter are lifted sufficiently high to clear the delivery rollers and pass over the top of the storage pockets. The crane is then moved transversely until it reaches a position directly over the pocket into which the bars are to be deposited. The 5in. frame is now lowered until the bars are a short distance above the bottom of the pocket, when the hooks are opened and the bars are permitted to drop into the "U's."

At the lower end of the storage pockets are placed travelling electric shears (Fig. 19) running on a transverse track. When an order for odd bars is to be filled from stock, a pair of tongs is fastened to one of the 350ft., or shorter, bars of the specified section resting in the storage pocket. By means of a rope attached to the tongs and a nigger-head extending from one of the gear shafts of the shear, the desired bar is dragged from the pocket and entered into a pair of pinching feed rollers which feed it through the knives of the shear. The first end is now cropped and the bar is again advanced until it strikes the adjustable stop behind the shear, when it is cut to desired length. Merchant bars of varying length may therefore be cut from one long bar without unnecessary waste of good stock; the only loss in the 350ft. bar being one short crop end, and, possibly one " short " at the rear end of the bar.

The storage system is, as explained, a successful solution of the problem of manufacturing bars in such a manner that small and varied orders for ordinary sizes may at all times be filled promptly and with minimum waste. During the years of my practical experience, I have a great many times been crippled and held back by the impossibility of quickly obtaining merchant bar, and would, if I had known where to secure prompt

delivery, unquestionably have gone to the maker who could guarantee it. Nothing has been more usual than to have it explained when placing an order, that as the quantity wanted was so small, the manufacturer could not afford to change rolls in order to make the bars required, but must ask his customers to be patient until sufficient orders for the same section had accumulated to justify him in making the roll change. A moderate sized billet storage makes it practicable, and economical, to store standard sections of bars for the immediate execution of small and urgent orders.

An installation such as that of the Carnegie Steel Company would probably cost as much as £200,000. It is, however, not necessary to build so large or complete a plant, or to go so far in the rolling of long lengths, which require corresponding buildings, cooling beds, and spare storage.

The Deering-Harvester Co., of Chicago, who for their enormous output of agricultural machinery, require 80 different sections of squares, rounds, flats, channels, zeds, ovals, half-rounds, crosses, and angles, are now building a merchant mill which will be capable of rolling sections covering over 75 per cent. of their tonnage.

This mill, which consists of a 14in. roughing train of eight continuous stands, and the usual six bull heads, will have a cooling bed 250ft. long. It will be driven by an engine of 1,200 H P. The billets will be heated in Morgan Continuous Discharge Furnaces, slightly modified from those previously described. The entire plant, except the cooling bed and boilers, is covered by a building 80ft. wide by 360ft. long. This plant will probably cost less than one-third of the sum expended for the double storage Carnegie Mill.

The effect of these new merchant mills on the older bar mills in the United States will be disastrous when the present demand and large margin of profit is reduced. By the new system bars can be produced at but little more than half the cost of the older mills. The stiff, well made, and easily adjustable mills maintain better and more correct sections, roll lengths heretofore considered impossible, and the entire length of bar makes the finishing pass at a uniform temperature. The steel, uniformly treated and cooled on the gravity cooling beds, is more uniform than steel of the same composition rolled on the old mills. The great capacity of the mills, and the stock kept on hand, enable their owners to supply customers more promptly. As a consequence, the bar business in the United States is more and more gravitating into the hands of a few large and well-equipped manufacturers. The public is unquestionably a gainer by the change, though the older and less fully equipped mills suffer.

The Continuous Mill as an invention is, as above stated, old. Anybody may build a continuous mill who is willing to pay for his experience. What has kept the Modern Continuous Mill a speciality of one firm is the amount of valuable experience acquired during years of work, and the

many specially designed accessories which go to make the Continuous Mill plant into an organised unit. It is not easy or profitable for general engineers and builders to enter the field where so much experience and knowledge of the minutest details is requisite for the achievement of success. Thus it is that the Morgan Construction Company, led by the man who made the Continuous Mill what it is to-day, still remains alone in the field. Certain other firms build partly continuous roll trains, and make arrangements with the Morgan Construction Company, by which they secure the right to use their specialities. But still it is the Morgan Mill, and the Morgan system, which to-day alone represents the highest achievements of economy and technical success in the field of continuous rolling of billets, rods, and light merchant sections.

THE DISCUSSION.

THE SECRETARY read the following communication from Mr. W. J. Foster:—

The Morgan Continuous reheating furnace and rolling mill is a very ingenious contrivance.

One important remark made by Mr. Sahlin requires serious consideration, viz. :—That it is not intended to put a mill down just the same as those at present at work in the United States, but that improvements are intended.

From an economical point of view this must necessarily be so. If we do not go further than what is actually being done at present, we shall, in a few years' time, find ourselves behind again. I am sure there is still plenty of room for improvement in the manufacture of iron and steel.

Although the fuel consumption in the Morgan Continuous furnace is only 150lbs. per ton of billets, I estimate the actual loss of heat in this case at 71·4 per cent., and, consequently, the combined efficiency of the gas producer and furnace is only 28·6 per cent.

This may be explained as follows :—The coal required to heat one unit of iron (specific heat = ·12) to a temperature of 1,300°C = 156 calories, The coal consumed in heating one unit of iron to 1,300°C, as given in Mr. Sahlin's figures (150lbs of coal per ton of billets) would be ·0669 unit. The heat generated by the complete combustion of ·0669 unit of coal containing 65·75 per cent. carbon and 8·25 per cent. of hydrogen would be 545·5 calories. The loss, therefore is 71·4 per cent.

The above calculation does not take into consideration the heat developed by the partial oxidation of the iron, owing to lack of informa-

tion as to the amount of iron wasted during reheating. Nevertheless, it is evident that this loss is reduced in proportion to the rapidity of the process.

In some cases I find that if the whole of the heat evolved by the oxidation of the iron during reheating could be utilised, it would be sufficient to heat the iron white hot without the expenditure of any external heat whatever.

If Mr. Sahlin's paper induces Midland capitalists to modernise, we shall have no foreign billets for some time to come.

Mr. H. Kirk (Workington): This paper is rather out of my latitude, as I don't go so particularly into the mechanical part of iron works' practice as into the metallurgical part. When I heard, to-night, the wonderful progress American ironmasters were making, I could not help thinking about one of the American papers which sent a man to Niagara to write some poetry on it. He went to Niagara day after day, and at last he wrote:

> **Niagarer! Niagerer!**
> **You are, indeed, a staggerer.**

and then he drowned himself. It seems to me that our operations in this country are so very small in comparison with those of America, that it would be very difficult indeed to adopt continuous rolling on a large scale, so long as we are split up (as at present) into different firms and companies, each doing a little. It would require rather a large amalgamation to adopt such machinery successfully. I don't think there is a firm in the United Kingdom who could find orders enough to keep plants going of the size described to-night. And to go on week after week, and year after year, finding enough demand for such machinery—well, it is indeed (as the Niagara poet said) "a staggerer." Mr. Sahlin has given us a most interesting lecture, one of the most interesting I ever heard in my life. It must be a magnificent thing to be able to have such machinery, when you have enough capital to acquire it and sufficient demand to keep it in operation.

Mr. L. D. Thomas: We have been led to-night over regions quite new to this country. And I am afraid we shall have to give in to the Americans on the question of the magnitude of their operations. Land is so dear in this country that it is initially expensive to put works down of that size; but, if we could have mills of that kind, about three would be enough in this Kingdam—one in Scotland, one in the North of England, and another in the Midlands. We have some cause to be thankful that we are Englishmen, seeing that the first attempt to make a continuous rolling mill originated in England, and the idea was then taken across the water to the new country. Mr. Sahlin gave England credit for bringing the continuous mill to a successful issue, and allow me to tell you that Mr. Morgan was a Welshman. Wales will hold its

own. Some people are very fond of twitting one about Wales. No one need be ashamed of being a Welshman. You must give us credit for being always in the front rank in the manufacture of steel and iron, and in engineering we can claim a fair share of praise. If you study the history of our country for the last century you will find Welshmen very near the top of the tree. Look again at America; who were the pioneers as regards blast furnaces, iron making, and other kindred manufactures there? Who is at the head of the tinplate trade there? Welshmen are also safely holding their own as makers of steel, and last but not least, we have one of the descendents of Morgan Mwynfaw bringing this grand mill to perfection. Well, putting all fun aside, at one of our meetings some two or three years ago, the topic of guide mills cropped up. I said English ironmasters were far behind and they would have to make up, and I suggested that our guide mills (10 inch mills) should be built on a quite different form to what they are at present. To begin with, we must have much higher speed than it is possible to get as at present arranged, and I suggested that we ought to have piles, or billets, of 150lbs. or 200lbs. weight. That would mean much less waste. One gentleman said that could never be done, because one end of the bar would be cold before the other could be rolled; but we have heard to-night that it *can* be done in some cases in America, and I think it could be done, to some extent, in this country. Some of the details of these new mills are beyond my comprehension, but the results are very good. The finish of the iron is an important matter, because English manufacturers are tied down to a certain specification. It must be exact as to finish as well as other points. In America, the makers have more latitude; that is another advantage they have over English manufacturers. With all their great works, modern machinery, and up-to-date processes, they do not seem to be able to obtain as good a finish as the British manufacturer, aided by the skill of British workmen. We can honestly take *that* credit to ourselves. You will, I am sure, allow me to say a word on another point. Tinplates are being made freely in America, but if they were put through certain assorting rooms which I know of in this country, they would be all thrown out as "waste."

Mr. J. Fieldhouse: I have read the paper and have also listened to the speakers to-night, and a number of points have occurred to me, as a practical man. Continuous rolling is not a new idea. A continuous mill was working forty (40) years ago. Mr. William Beasley, of Smethwick, invented one. It was abandoned because of similar difficulties to those which present themselves to me as to the present mill. The author has not told us of those difficulties. A difficulty might arise if there was a stoppage in the first set of rolls. The piece might be cut off before it came to the next set; but suppose the piece cut off got into the next rolls and made a jamb, how long would it take to get it out? We know very well it would jamb up the guides and

cause a great deal of trouble and labour, because we know what steel is when jambed up. Evidently such difficulties would be met with. Another great difficulty is the adjustment of the guides. How are the small ovals turned up into the number five round holes? I have to adjust guides to the one-thousandth part of an inch. I am aware that the rods are not required to be exactly round, yet if the piece is not going through accurately, the guides will not last long. The piece must go through straight or the guides will begin to wear, and about two billets would spoil them completely, as well as make an imperfect round. The adjustment of the guides is no doubt a great hindrance.

The author mentioned the beautiful colour which is got on hoop, and which is appreciated in Birmingham. Another difficulty presents itself to me here. I cannot imagine how the strip as thin as a piece of paper can travel from one pair of rolls to another. How is its own strength going to carry it through into the hard rolls? But we will suppose it *is* done. The hoop must also be scraped. Then again, the last hard roll must work with friction. It looks as though there must be sticking in spite of the greatest care. About three of the steel billets, which are 300lbs. each, would be quite sufficient to cause trouble. You would want to alter the journey about every six pieces. You would also want another journey on the hard rolls. The guides have to be moved to bring them up to another journey, for finishing purposes. Another difficulty is the strand (the pieces before going into the hard rolls). The journey there does not last very long, and when that goes wrong, the result is a bad and uneven hoop. I don't say it cannot be done. It can be, and has been, done to advantage; but not with very small work. Small work will entail great loss, of which the supporters of the system do not tell us. I should never think of rolling T. and Z. iron with a continuous plant. It might be accomplished by half doing it, and completing in the finishing rolls after; that might be a good idea.

Then as to roll-turning. The wheels are all arranged to go at certain speeds, so that there may be no pull or stretch. If you alter the diameter of one roll, you have to change all the rolls. If one pair of rolls is made smaller, the next must be in proportion. That is a point which I would like explained. I now come to the roughing-down rolls. The paper says the rolls are placed against each other. Suppose it is a 16 inch mill. He speaks of a 4 inch flat bar being turned up to an angle of 90 degrees. I cannot imagine how the guides twist up the pieces in such short distances. I should like such an arrangement as would give a large bar a chance to twist. I cannot comprehend how it is managed. Mr. Sahlin shows us a new type of mill, which I will call a box-mill, The iron goes into a box, passes round a table and out again. Suppose anything happens inside the box. How do you get at it?

In conclusion, I wish to thank the writer for his valuable paper, and

hope he will be able to explain how the difficulties of which I have spoken are surmounted.

Mr. J. RAYBOULD: When rolling angle iron, we get a greater strength in the root than on the sides, and this greater body of metal retains the heat longer, therefore contraction is going on longer in the root than on the flange. To meet this difficulty we have to bend the angles when hot, in the opposite way to which this unequal contraction would draw them. We put light angles in a sweep of about 2ft. in 40ft. Now what depth would be required for the angles the author informed us are rolled in lengths of 300 feet? The same difficulty presents itself in other sections, *i.e.*, unequal angles, bulbs, unequal tees, with stronger head than stalk. The greater contraction is going on in the stronger part of the section, because it retains the heat longer; consequently, when these sections are cooled they will be full of crooks and curves, which will vary according to the varying strength of the sections rolled.

Further, there is the possibility of getting the top roll slightly "over" or out of perpendicular. Although that pair of rolls receive the *equal* section from the previous pair, they would not deliver it equally. Suppose it was one of those 3in. by 3in. by $\frac{1}{8}$ angles of which the author spoke, but one side is 10 gauge and the other 11 gauge, this slight varying of the strength would have the effect of throwing the finished angle out of its course, or delivering it twisted, which in a 300ft length would be a tangle that would take a long time to clear out. Things like this happen in the best adjusted mills.

Then again, with small rounds there is the possibility of the guides wearing unequally, which they do even in our small mills, running short lengths, however careful the roller may be. The effect of this is, that the "oval" is presented to the finishing rolls unequally, and instead of getting a round you get an oval.

These are some of the difficulties that present themselves to my mind, in connection with the continuous rolling mill, and to a great extent, *finish* will have to be sacrificed for quantity.

I have been very much interested in the paper, and can testify to the help it must be to those of us practically engaged in the iron trade.

Mr. W. J. FLAVELL: I should like to add my testimony to that of the previous speakers as to the great pleasure I have received in listening to the paper. One of the difficulties here, in this district, is the wear and tear of the bearings, although we do not work at such a speed as they do in America. Various methods are adopted in this country to keep the bearings cool and prevent them wearing out. Perhaps Mr. Sahlin can make some suggestion which may be useful to us in the Midland counties.

Mr. SAHLIN: In the first place let me express my appreciation of the interest you have taken in this paper. I might say much more, but I am afraid that I should try your patience too far.

Many doubts have been expressed as to the practical possibility of mills such as I have described, but there is one great fact which we cannot get away from, viz., that these mills do run, that they produce the great outputs which I have described, and do give general satisfaction. It is true there are difficulties, but these difficulties have been overcome, though it has taken 34 years of constant work by some of the brainiest men in that brainy country across the sea to do so. There is something tangible in the objections which have been made when starting out from our experience in this country, but I wish to say that whether I now can answer these doubts and questions satisfactorily or not, you must bear in mind that the magnificent photographs which I have shown you have not been produced from nothing, but represent actual machines working in the most successful and effective works of to-day.

One speaker questions the possibility of rolling hoops in great lengths, yet hoops almost a mile long are being constantly rolled at the mills of the Union Works at Youngstown, O. I admit that hoop iron is a difficult product to handle, that it acts just like wet paper; but this fact only accentuates the efficiency of the mill which I have described.

Mr. Foster has spoken of the Morgan furnace and producer having only an efficiency of 28 per cent. of the theoretical heating value of the coal. Indeed, I have never for a moment supposed that the efficiency would be so high. The air passes into the furnace at about 900 degrees Fahr. If the outgoing gases were of a lower temperature than this, the air could not be heated, and the efficiency of the furnace would not be increased. It is an object to be wished for that some engineer may succeed in designing a more effective furnace and more effective boiler. This is a problem for the coming generation. It is too late for us who are now turning grey to do so.

There is no doubt that one must take better care of the heat in our metallurgical processes. One speaker has pointed out that there is a great waste of heat in the blast furnace. Let us get hold of that heat and we will revolutionise everything pertaining to iron and steel making.

Mr. Kirk says that in this country we are divided up. This is unquestionably true. We are divided up more than we can remain if we are to hold our place. I have just been across the Channel on a visit to Germany. The Germans are aggressive people. They are very sharp and clever, and they know their business down to the tips of their fingers. I consider them more dangerous to us than the Americans. An ocean of 3,000 miles is in itself some protection, but the Channel is not very wide.

Several speakers have called attention to the fact that we, in England, cannot do what is being done in the United States. I fail to see why not, because the advantage is by no means all on their side. Look how they are handicapped by distances. The Lake Superior iron ores have to be hauled 60 to 80 miles in cars to start with. Then there is a voyage of from 800 to 1,000 miles to the lower Lake ports, and finally there is an additional railway haul of about 150 miles to Pittsburgh. The iron-masters also have to carry their coke about 70 miles from Connellsville to Pittsburgh; and if for export, the product has to travel about 375 miles by rail to Philadelphia or Baltimore before reaching the ocean going steamers.

But here, in Staffordshire, you have everything right at hand. In that respect you have much greater advantages than Pittsburgh. You must give the Americans their right proportion of credit for their enormous energy, their brainy endeavour and application. For my part I must say that I have lived in America 20 years and in England for more than four years, and the longer I stay here the more convinced I am that the Americans have not such greatly superior advantages. Taking the British Empire as a whole, you have a population three times as great as that of United States to cater for. You must make your people wake up. You must create conditions, and you must remember what your forefathers have done before you. Why should you not accomplish as great things, commercially and industrially, in this rich island, with all its money, as do other nations? France and Germany are not too small for such mills, then why should England be? But Mr. Kirk is right, we work in England too much by individual effort. We would do better by hearty co-operation with one another. It would thus be easier to regulate the supply to the demand, and to obtain better results. The people will soon come to see this, and things will undoubtedly be changed. If you can produce an article well enough, and cheaply enough, you can sell it. This is an axiom. Yet up to the present in this country we are doing little to cheapen and improve our manufacture, especially of merchant bar. There is room for great improvement in this manufacture.

Mr. Thomas has said something about the ancestors of some Americans. Mr. Morgan is of Welsh extraction, and took with him to America that great tenacity and persistence which is typical of his ancestral race, and which brings them to the front wherever they go.

It has been pointed out that it would not be possible to roll longer bars, because the last end of the bar would become cold. This is very true with the mills with which you are familiar in the Midlands. But in the Morgan Mill special arrangements are made by which it is possible to work the bar at the same temperature throughout this length. As to exactitude, a mill working steel at uniform temperature, and with independent housings, is very much more likely to give you a correct

section than a mill in which one roll must be adjusted at the same time for several passes. I took pains at the beginning of my remarks to point out that the strictly continuous process is not suitable for finishing accurate sections. For this reason the Morgan Bar Mill is a combination of a continuous running mill with several independent trains running at different speeds for finishing. I do not believe there is anything in the remark that America is less particular about its sections than England. During many years of experience I have found that the American demands a good article as well as the European.

The Morgan Merchant Mill is, contrary to what has been pointed out in discussion, most suitable for finishing various sections. Of 84 different sections required by the Deering Harvester Company, the same 11in. Morgan Mill will roll 64. The rolling of angles offers no difficulty on the Morgan Semi-continuous Mill. The angle bar being about 300 feet long will straighten itself while resting on the cooling beds without any cambering.

The guides used in the continuous mill are very cheap. They are held in place by a simple wedge and are exchanged in a few seconds.

From beginning to end, each section of the rolling mill can be independently adjusted. If a billet in the process of being rolled should stick in a guide, it is at once cut in front of the first pair of rolls and between the roughing and finishing train. A half-inch square bar will, therefore, be sent out from the roughing train. The clogged guide can be removed in a couple of seconds and a new guide substituted. The mill is never stopped for making these changes, and the entire loss in material will be a few lbs. of half-rolled wire rod adhering to the guide.

As an indication of the continuous operation of the Morgan Rod Mill, I may say that at one particular works the greatest day's work during one year amounted to 192 tons; the average day's work during the year to 162 tons, and the lowest day's work 125 tons. The maximum work was, therefore, only 20 per cent. above the average.

In regard to question as to the distance between rolls of the Morgan Continuous Mill, this varies between each pair of rolls, and has been determined in the course of a long experience. The housings never stand closer to one another than will allow ample room for the attendants to adjust any part of the mill.

A question was propounded as to the material used for gearing. For slow running gears we use machine moulded wheels, cast in charcoal iron or steel. For swift running pinions, machined wheels of forged steel are used. The bearings are cast in white metal. To renew the bearings a special set of jigs are furnished with each mill, also spare housings for roughing and finishing trains. The finishing train runs at a great velocity, the last pass in the rod mill is given a peripheral speed of about 2,000 feet per minute. All bearings are of extra large

dimensions and are practically run in oil. The pinions run wholly in oil and without noise. These hermetically enclosed machined pinions are a coming thing not only for small mills but also for larger ones.

I believe that I now have answered the majority of the questions brought out in the discussion, and I thank you for your patience in listening to these long explanations.

The President: I have pleasure in proposing a vote of thanks to Mr. Sahlin. His remarks lead me to speak once more of the need of a waterway from Liverpool to London. We should not then be so very much in the hands of the railway companies. If Mr. Sahlin knew how we were crippled by the railway companies in Staffordshire, he would understand how it is we do not get on quite so fast as he would like. He speaks of our advantages, but when we tell him our railway rates are three or four times those charged in America, he will understand how we are crippled.

The proposition was seconded by the Vice-President (Mr. W. Brooks) and carried unanimously.

The Seventh Meeting of the Session was held at The Institute, Dudley, on Saturday, the 4th of April, 1903.

In the absence of the President, the chair was occupied by Mr. W. Brooks, Vice-president.

The minutes of the previous meeting were read, adopted, and signed.

Messrs. William Lisle, W. J. Onions, and W. H. Shorthouse were elected members of the Institute.

Resolved, that Messrs. Richard Round and James Raybould be appointed auditors of the Institute accounts for the year ended 31st December, 1902.

The Chairman introduced Professor Ashley, who said: I hope you will not think I have brought you here on false pretences because the title of the paper is rather different from that originally annonnced, which was "Works' Management." I thought that it would be wiser for me to lay before you some general considerations, and try to get some information and guidance from you this evening, and perhaps in a couple of years' time, when I know rather more about the subject, I may be able to speak to you more wisely upon works' management. But, as you will soon see, the subject of my paper to-night is not at all remote from the topic originally announced

Professor Ashley then read the following paper :—

THE UNIVERSITIES AND BUSINESS.

By W. J. ASHLEY, M.A., M. Com., Professor of Commerce in the University of Birmingham.

I am very glad to have an opportunity to lay before a body so closely identified as yours is with the staple industry of the Birmingham district, some considerations concerning the functions of the University of Birmingham; and of its new Faculty of Commerce.

The creation of the University, and of that Faculty, are not isolated events. They are connected with a great movement in the higher education of this country,—a movement which may indeed die away, but which, I trust, will have a far-reaching and permanent effect.

1.—Let me begin by trying to explain to you what seem to me the leading ideas of this new University movement. The first and most vital is the belief that University education must be enormously widened in its range. It must no longer be content to confer general culture on a certain part of the leisured class, and give a professional training to clergymen, schoolmasters, and doctors; it must bring within its scope the whole of the higher professional training of the country; and by professional training must now be understood, not only the work of the so-called learned professions, or even, in addition thereto, such new professions as those of the varied branches of engineering; but all those intellectual pursuits which involve industrial or commercial leadership, and which call for the intelligent application of general principles.

We in England have hitherto prided ourselves on our enterprise, originality, and courage; and we have been inclined, perhaps, to look down upon France and Germany and other continental peoples, as attempting to make up for their defects in these directions by a formal training. But the United States are showing us that it is possible to combine all the advantages of Anglo-Saxon enterprise and individual initiative with the additional advantages of systematic preparation for a man's work in life. Of course America is full of self-made men, who have had no early advantages in the way of education; but a Carnegie or a Schwab is an exception which will break all rules: and men like these know how to secure the co-operation—are ready to pay highly for the co-operation—of the most thoroughly trained men they can obtain. When I went over the Home-

stead Works some two years ago, it was amusing to see how anxious the colleagues of Mr. Schwab were to disabuse my mind of any mistaken impression I might have on that matter, and to point out to me distinguished graduates of Princeton and Columbia at the head of several of their great departments.

To bring all the intellectual occupations of the country within the range of the University will add to their dignity; and will enable them to be studied seriously and consistently. And the gain will be great to the older studies. The presence of a very large element in the undergraduate body whose studies have a direct bearing on their future careers, will strengthen the spirit of strenuous sincerity among all the students; and whatever danger there may be in the growth of technical studies will be counterbalanced by the zest which comes from practical purpose.

The distinction, indeed, between "culture subjects" and "technical subjects," between "pure" and "applied science," is one which breaks down when applied to higher education. Of course in its lower ranges the distinction is tolerably clear; and everyone who has the cause of true education at heart must protest against the tendency to insert subjects like shorthand into the already crowded curriculum of the elementary school. But technical or applied science studies as they will be carried on at a University are necessarily in the very closest touch with the most abstract disciplines. It will be remembered that it was while pursuing investigations into the fermentation of yeast that Pasteur arrived at those wonderful discoveries with regard to Bacteriology, which are transforming modern medical science.

This, then, is the first and leading idea in the new University movement—the idea that all intellectual pursuits should be brought within the range of University training; and that the University should no longer be given up to one or two professions, or looked upon as a luxury for a few exceptionally favoured individuals.

2.—But it must be evident that if the duties of the Universities are so conceived, no one University can satisfy the needs of the whole country. Even if the two older Universities of Oxford and Cambridge had far larger funds at their disposal than they are at all likely to obtain; even if their organisation possessed more elasticity than it does at present, it is out of the question that they should be able to control the whole of the professional training of what may be called the "directing and governing classes" of England. It would seem to be evident that some degree of specialization is necessary. Moreover—as an Oxford man, I say it with sorrow—the alienation of the business classes of England from the two older Universities has gone so far that it is practically hopeless to expect to bring them now within their embrace.

The problem is not primarily to divert from Oxford and Cambridge

those who now resort thither, not even to turn the attention of those who resort thither to new subjects; but to induce that vastly larger number of young men to submit to a definite and serious training, who at present are "pitchforked" into the workshop or office at seventeen, and get no systematic training at all. It is this feeling of the necessity of more or less specialized Universities—Universities which, while laying foundations for general culture, shall yet construct their curricula with an eye to the needs of particular sections of the people—which explains and justifies the recent multiplication of Universities in this country. For Birmingham does not stand alone. Not to mention the University of London, which has recently entered upon a new career as a teaching body, while before it was a mere mechanism for examination, the Privy Council has recently advised the Government to break up the federal Victoria University, and to grant charters as independent Universities to its constituent colleges at Liverpool, Manchester, and Leeds.

The chief justification for the establishment of independent Universities at the four great provincial towns, Birmingham, Liverpool, Manchester, and Leeds, is that only in this way can the commercial and industrial requirements of the great districts surrounding them be properly served.

Liverpool, with its shipping and foreign trade; Manchester, with its cotton manufacture and the allied industries; Yorkshire, with its woollen and worsted manufactures; Birmingham, with the iron manufactures of the district and its hardware trades, present groups of interests which are all tolerably clearly marked.

3.—Now let us come to the special case of Birmingham. As you are aware, the University of Birmingham has recently established a department of Metallurgy, presided over by a man of science who enjoys, I have been delighted to find, the highest reputation among the practical metallurgists of the country. It already has a flourishing Engineering Department. It has boldly resolved to spend the greater part of its available capital in the erection of magnificent blocks of building, at its new site, for the three departments of Engineering, Mining, and Metallurgy—buildings which it intends to equip on the most liberal scale with all the apparatus needed for practical teaching. Realising that it must succeed in these directions if it is to succeed at all, the University is prepared to take its chance with these departments, in the confident expectation that, if they succeed, the Midlands will not keep it long waiting for the buildings which other departments will require.

And finally the University has created a Faculty of Commerce. The word "Faculty" has been chosen not from any self-conceit; but to emphasise a principle and give expression to a hope—the hope that it will at no distant time have a body of teachers as numerous as any of the older faculties; the principle that commercial life calls for a serious preparation like any other pursuit, and ought not to be left outside the

sacred limits of University life. To place a Faculty of Commerce side by side with the Faculties of Arts, Science, Medicine and Law, was a significant, and in the best sense, a radical step, worthy of the best radical traditions of the Midlands.

Before I ask you to consider what the University of Birmingham can do for the training of the men who are to manage the ironworks of the Midlands, let me make quite clear to you the method on which the University proposes to work. Single courses of lectures on particular subjects will be open to all who are qualified to take advantage of them; and it is quite possible that some of these may be taken by men who are actively engaged in professional work. But it will not be possible in this way for anyone, while still engaged in business, to take a complete and systematic course. The University does not propose to develop a series of Evening Classes. It addresses its appeal primarily to young men who have reached an age at which they are capable of thinking for themselves, and who are ready to come and devote the whole of their time for three years to a systematic curriculum. It does not do this simply because it has not a staff large enough to enable it to duplicate its work; it does it also on grounds of principle. It believes that, leaving exceptional cases out of account, men will do far better and more thorough work if they can give all their fresh energies to their studies, instead of bringing to them the jaded odds and ends of their working days.

We in England have hitherto been too anxious to provide for the exceptional clerk or mechanic already engaged in some occupation, but anxious, as the phrase goes, "to improve himself." Such men are deserving of all sympathy and encouragement, but they will be provided for in other ways than by the University. The result of thinking primarily of the immediate needs of such exceptional men is that, so far in England, with all our outcry for higher technical education, we have hardly got beyond the stage of Evening Classes.

In America it is altogether different. There are great institutes, like the Armour Institute at Chicago, which are designed for the needs of this class; but the great Technical schools to which the Captains of Industry look for their experts—schools like the Columbia School of Mines, the Massachusetts Institute of Technology, the Scientific School of Harvard University or of Cornell University, are great day colleges which take young men at 18 and keep them for four years, precisely like the elder English Universities. It is a most remarkable fact that so practical a people as the Americans should have adopted, without hesitation, what to many old-fashioned English business men seems so expensive a procedure.

It is, of course, a fine thing that a young man engaged during the day,

let us say as a draftsman, should have sufficient ambition and perseverance to attend evening classes; but it is at least an equally fine thing for parents and relatives to contrive to send a boy to college instead of putting him to earn wages at the earliest possible moment; even if they have to borrow money from friends, which has afterwards to be repaid.

Moreover, in America, the poor boy of ability who is "worth his salt" prefers to save a little money and go to college for a year, and then go back into an office or works for a couple of years or so, and save enough money to return and finish his college course. Such cases I have frequently come across in my American experience. And, besides, college and business life are nothing like so separate from one another in America as they are in England; and it is the commonest thing in the world for a college boy to take a post during the long summer vacation in order to help to cover his college expenses, with the incidental advantage of gaining some practical experience. Certainly there could not be found two opinions in America on the question as to whether a regular college course, even if it has to be occasionally interrupted for a time, is not, as a rule, far more satisfactory in its result than any series of evening classes, however protracted.

The University of Birmingham is following the example of practical America. We want the ambitious young men of the Midlands, who have already received up to the age of 17 or 18 a secondary education, such as our Grammar Schools or even our Higher Grade Board Schools provide, to come to us for three solid years, even if it means a good deal of pinching and contriving, and, above all, a good deal of faith; and if they do not see their way for three years, let them come, at any rate, for one solid year. They may be able, by and by, to complete the course. If not, even that one year will be of great value to them.

4.—Let us come now to somewhat closer quarters with the professional training of men for the management of iron works. On this subject I have my own views; but I am much more anxious this evening to get the views of my audience. All iron works are, of course, not the same kind of works, and even works of the same kind may be managed in different ways; but I suppose there is a tolerably clear distinction between the Mercantile and the Executive or Manufacturing departments. There is the task of superintending the process of manufacture, and the task of finding a market for the product when made. It is quite clear that the gifts required for the one are not necessarily the gifts required for the other. A man may be thoroughly acquainted with the latest methods of production, and yet have little skill in anticipating the market. On the other hand, a man may have no more knowledge of the details of processes than any intelligent person can pick up who keeps his eyes open; and yet may display positive genius in the purchase of his materials, and the sale of his finished goods.

I suppose these two functions are often separated into two different offices, that of the General Manager, whose function is primarily commercial and administrative, and that of the Works' Manager, whose function is primarily manufacturing. Or it may be that a Managing Director takes into his hands practically the whole of the commercial side. But, however the two functions are distributed among the officers of the concern, it is clear that the controlling and dominating one must be the commercial.

The technical perfection of the product is valueless unless it can be profitably marketed; and so it is noticeable that the great Captains of Industry in the United States—Mr. Carnegie being the most striking example—have been great industrial strategists rather than great technical experts. I suppose there is hardly a process employed in the Homestead Works which was not derived from English or German practice. What Mr. Carnegie has done has been, first, to apply the best European methods on an unprecedentedly large scale; secondly, to substitute immediately and without hesitation newer mechanism for older, if it presented a reasonable prospect of greater economy; and thirdly, and above all, to control the supply of all necessary raw material—the iron ore of Lake Superior and the coking coal of Pennsylvania—as well as all the necessary means of transportation by land and sea. The same is true of the great Petroleum and Sugar magnates. Their powers have been those of acute commercial analysis; they have analysed the several elements of which the cost of production was composed, and having reached a policy accordingly, they have resolutely carried it out.

But although the commercial function must be the controlling one, however distasteful the recognition of this fact may be to the scientific expert, it would certainly not be expedient to train men exclusively either for that or for the other. Men who enter business at twenty or twenty-one cannot be by any means certain in which direction their powers will develop, or find opportunity for exercise. Moreover, even if a young man is going to concern himself mainly with the manufacturing side, it will certainly be the better for him to know something of commercial methods and principles; while the young man who is going on to the commercial side ought on his part also to know a little, at any rate, of the processes of manufacture—it will make his work more interesting for him, and it will enable him to keep his eyes open to the possibility of technical improvement.

Accordingly, I anticipate having at the University two distinct classes of men. First, the men who are receiving a training which is in the main Commercial; whose life-work in one way or another will have to do mainly with buying and selling, together with such administrative duties as are involved in the control of bodies of workpeople. But if such men have any sort of notion of the particular business into which they

are likely to go, then I shall advise them to take two or three courses in that applied science most closely connected with their future occupation, *e.g.*, in Chemistry, Engineering, Mining, Brewing, and, of course, in Metallurgy.

The other class will consist of men who are being trained to be technical experts, as Engineers, Mining Managers, Practical Metallurgists, etc., etc. These will take a course of instruction, designed five parts out of six, perhaps, especially for the technical requirements of their future career. But if they are well advised, they will take two or three courses of Commercial Lectures. They ought, for instance, to take such a course in Accounting as will enable them to understand the keeping of books, and the chief items to be considered in a system of cost accounts. They ought also to learn about the organisation of their business in great rival countries. The man, for instance, who is going to be engaged in the iron trade of South Staffordshire, ought to be pretty well informed about the iron trade of South Wales, of Cleveland, and of the West of Scotland: and also about the iron trade of Pittsburg and of Westphalia. But above all, he should have been given an opportunity to consider quietly and systematically some of the chief commercial problems which present themselves to business men. The question, for instance, as to where works should be located, and the advantages and disadvantages of different policies in regard to that matter; the question of the desirability or otherwise of combining different manufactures, either representing different stages in the production of the same thing or the production of altogether different things; the causes which have led to various forms of combination among manufacturers, the advantages they are designed to secure, and the dangers to which they are exposed; the question of means of approach to the ultimate consumer, whether through wholesale merchants, factors, agents, or what not; different methods of remuneration—piece work, time work, bonus, contract, and so forth, looked at from the point of view of industrial efficiency; the valuation of goodwill; the phenomena of crises and trade cycles; and above all, the policy of selling price in its relation to cost. All these are subjects upon which it must do him good to have reflected a little before he actually gets into the vortex of practical life.

You must not think for a moment that these are subjects upon which any sensible Professor of Commerce thinks he has a cut and dried doctrine to be crammed up by the student and then applied afterwards to particular cases. The duty of the Professor of Commerce is not to formulate an abstract doctrine of his own, but to act as intermediary between experience and ignorance. On "Commerce," so understood, there exists as yet no text book; but there is abundant material in the recorded experience of men of affairs which needs only to be got together, put into systematic shape, and the general principles disentangled

from the mass of irrelevant detail. Nor, of course, am I so foolish as to suppose that actual business problems repeat themselves in precisely the same form as before. We do not expect that men will learn as students the wise policy for them to adopt and then have nothing to do but to carry it into effect; life is too complicated for that. What I do believe is that on questions such as I have mentioned a good many general considerations can be presented to a student in such a way as to make him think, and that the habit of systematic thinking on business problems will save him a good deal of subsequent discouragement and lost time.

ADDENDA TO PAPER.

The fact is, we in England are still under the influence of the old opinion that the Universities are only places for well-to-do people, who can afford to let their sons stay there for three years. That is not the conception that the Germans and Americans have. To them the University is not a quiet retreat, a long way off from the industrial turmoil. The American University is a decidedly practical thing. I do not think you would find a fairly well-to-do man in Eastern America, or even a large shopkeeper, who did not have a son or nephew at College. Unless we are going to create Universities like that in England, we had better give up the job. Now, in order to get some information from you, to assist me in my work, I have drawn up some forms which I will distribute and then explain. You will see that the forms contain blank spaces for you to fill in, with the following nine headings:—Name of works; approximate number of men employed; chief manufactures; branches elsewhere; titles of chief officers; training desirable for general manager; training desirable for works' manager; name and address; position. The forms are headed "To be returned to Professor Ashley, University of Birmingham." Now, I should be glad if every gentleman here would, with a pencil, in an odd five minutes before the proceedings close, fill up these papers in an informal way, giving just as much or as little information as you like. First of all I want the name of the works, then, roughly, the approximate number of men employed, just to give me some idea of the extent of the operations. Then the chief things produced. Then I should like the titles of the chief officers and how the management is divided. For instance, you may have a managing director, a general manager, a works' manager, and a general secretary, and there may be other officers; or you may not have these; it will depend upon the kind of business, and the size. You may have to substitute managing director for general manager. I daresay many here went into the works when they were young, and made their own way, and consider that the best method. Well, if you think that, say so. But look at it for a moment from a rather different point of view. Let us suppose you have got on in your

own way and have been successful, and now you have a son who will have no need to go through quite the same struggle as you had to go through. You can give him certain advantages which you could not get yourself. Now what would you do with that boy if you looked forward to his becoming, let us say, a works' manager. Suppose you were Providence, and could give him just what training you thought best. Or, suppose you owned an ironworks yourself, and suppose it was a large ironworks, and you would like your nephew or son to take a leading part, and suppose he has been to a good Grammar School, say at Kidderminster or Wolverhampton. We will assume the moral virtues, and also perseverance and industry, and punctuality and so forth, and assume that you have this young man of seventeen and you would like him to be an important person in that business by and bye—now, if you were able, what sort of preparation for that position should you like to give him? That is what I want you to bear in mind when filling in the "training desirable for general manager," and also, to some extent, for "works' manager." If you will fill the form in and send it to me, together with any other observations on the subject that may occur to you, I should be glad.

THE CHAIRMAN: I think it would be best if they took the forms home to fill up and then posted them to you.

PROFESSOR ASHLEY: Certainly, if more convenient.

THE DISCUSSION.

MR. WALTER JONES: Personally I am very pleased Professor Ashley has given us this very interesting and practical address. We all endorse the Professor's opinion that it is a fine thing to send a boy to College; but as to the next line which says, "even if they have to borrow money from friends, which has afterwards to be repaid"—I am not so sure that that is a right principle. It might sometimes have very bad results, because if people get into the habit of borrowing money, they will continue to do so, and have less disposition to earn it so long as "fools will lend." That is the only point I disagree with in the paper. Most of you are well aware that a highly esteemed member of this Institute is also a professor at the Birmingham University, namely, Professor Turner. The Faculty of Commerce of which Professor Ashley is the Dean, is, I believe, a new faculty, and is likely to turn out a very good one. As a manufacturer who has worked up from a very small beginning, I appreciate the difficulties of a beginner, who has had no technical education, and who had to get what little was possible at evening classes after working hours, and the University of Birmingham will, I hope, assist such cases. It has done a great work already, and it will do still more in the future. I am sending my son to the University for a three

years' training, and I daresay there are other members of this Institute who are doing the same. English people are rather apt to pat themselves on the back and think there is no one on earth like them, and they are about the most conservative people you can meet with anywhere. Even people who are Radicals in politics are very averse to making reforms in business; they say, "I have always gone on on these lines, and I do not care to make any change." They will have to alter that sort of thing. The University of Birmingham will assist by training young men with new and more progressive commercial ideas. Our sons will have different conditions to face to what their fathers had, and therefore we are deeply indebted to Professor Ashley for the good work he has undertaken in the Midlands and for coming here to explain it. I have heard it said that if you have fifty English working men, you must supply brains for the whole of them. The English workingman, as a rule, does not trouble to think. So far as my experience goes, a thinker among them is the exception and not the rule.

Mr. Henry Parry: I have, on many occasions in this room, advocated the cause of commercial education, and am very grateful that Professor Ashley has been induced to come forward and explain to us this scheme of commercial education in the University of Birmingham. The great Napoleon once taunted the British with being "a nation of shopkeepers," and that taunt was very much resented by certain classes of society who were always very willing to make as much as they could out of trade without revealing their connection with it. That resentment exists, no doubt, to a large extent to-day, but I think it is a feeling of false pride. We are undoubtedly a commercial nation, and in order to maintain our position in the world we must make ourselves acquainted with the best commercial methods. To-day the classical training given at Oxford and Cambridge does not enable young men of wealth and station to become acquainted with commercial principles; yet when they have left their college and go out into the world, their names are sought by the company promoter to make his prospectuses more attractive, and having had no commercial training, it naturally follows that some very highly honoured names are often dragged in the dust. I am glad to think, however, that all sorts and conditions of men may now have some training in commercial matters. But this training ought to start somewhat earlier than at college. There are not many of us in this room who can afford to keep our boys at home until they are one or two-and-twenty. I know I cannot. I think the commercial course ought to begin at our grammar schools. Our boys are taught Latin and Greek as it was taught in the time of Edward the Sixth, and a commercial course could be introduced into those schools with advantage. Part of that course in Grammar Schools should teach a boy how to write a decent business letter. I remember, in the old times, it was a pleasure to read business letters, but now a days you get letters that might have been written by a mere schoolboy, and there is hardly anything more irritating than to

start in the morning with such correspondence. It gives an acid tone to all one does for the rest of the day. The average German letter writer is a model of sauvity and courtesy, and I think our correspondents might with advantage imitate the Germans in this respect. I must express my indebtedness to the Professor for his paper and the explanatory remarks with which he has accompanied it.

Mr. THOMAS ASHTON: The very able paper we have had from Professor Ashley to-night contains, among many other valuable features, a strong appeal to the young men of our Institute, and beyond them to the young men of our country, to emulate their young kinsmen in America, who are prepared to make great sacrifices both as regards sport, time, and money, so that they may acquire a thorough scientific and practical training for their various positions in life.

This appeal must not be ignored by them, unless we, as a nation, are content to lag behind in the race for the commercial and industrial supremacy of the world.

To foster this spirit of emulation, the powers that be must see that our educational institutions are levelled up to the standard of excellence now enjoyed by our great national competitors, and every facility given to the gifted, whether children of the poor or rich, to climb to the top of the educational ladder.

At present, graduates of our universities prepare themselves for business pursuits only in very rare instances. The army, the navy, or a professional sphere having greater attractions for them. On the other hand, the American graduate can frequently be seen working at the mechanic's bench or in the machine shop, and having completed his course of practical, as well as theoretical, training, his next step will be to occupy a leading position in some engineering work or as superintendent of some extensive rolling mills, showing that he is alive to the dignity as well as the emoluments of manufacturing enterprise.

It is of good omen that the Birmingham University, which has not been established a day too soon, is officered by professors who are alive to the necessity of adapting their curriculum to the requirements of the special trades and industries of the district. It is also most gratifying to us that the professors of Birmingham University recognise our Institute as an educational force. We claim Professor Turner as one of ourselves. Sir Oliver Lodge honoured us with an address of great interest and value, and now Professor Ashley has favoured us with a most excellent address on a subject of vital interest to this great commercial and industrial centre. This linking of professional and practical forces cannot but be of immense value to the movement for a higher technical training for the artisans of our country. And as the extensions now being carried out at the Birmingham University are likely to result in a greater specialization of subjects necessary to the thorough training of manufacturers, as

well as managers, connected with our staple trades, it is fair to assume that if taken advantage of by the young men of our district, there will, in the near future, be in evidence a better type of both, better for having received university training, and from whom much more will be expected, than from those who, under much less favourable conditions, have done so splendidly in the past.

I hope that we may be favoured with many other addresses from Professor Ashley and his distinguished fellow professors at our university.

Mr. JOHN FELLOWS: I think if we had been a class of students such as the Professor is in the habit of lecturing, we should probably be able to fill in these papers "while you wait." But as we are not trained to the business, I don't know that we shall be able to fill these up just on the spur of the moment When I do fill mine up, I shall give all the information I possibly can If the Professor is at any time in want of information, and will ask the Secretary of the University to apply to manufacturers in a large way of business, I think he will not have to complain that employers have not done their best to help him by supplying the information he wants. With regard to borrowing money to send lads to the University, I know that in many cases it is impossible to send them, unless the parents or other interested parties are prepared to make some sacrifice. I know a case of a young man whose parents were unable to pay for his education. He was at first a pupil teacher at a Board School. He then went to the training class centre, and after that his brother lent him the money to go to the University. Last year he got his B.A., and he is now in a position to commence to pay his brother back. In that case we must all agree that the end has justified the means. I am very glad that the University of Birmingham is endeavouring to develop the modern side, so as to be of the greatest possible use to the people of the Midlands in developing their trade and commerce. Personally, I feel sorry that the University was not established earlier, or that I was born so soon. I feel the disadvantage of lacking such information as is given at the University, and although many of us here cannot ourselves take the three years course, nor perhaps send our sons to do so, yet we can derive advantage from the various public lectures given by members of the University teaching staff upon metallurgy, commerce, and similar subjects, and we can read the books which the University issues or recommends.

Mr. WALTER MACFARLANE, F.I.C.: I am not quite sure that I ought to venture upon a criticism of the paper submitted by a Professor, but as he has been good enough to say that he is anxious to hear the views of his audience, I hope Professor Ashley will take the few observations I am about to make in the spirit in which they are offered. It is possible for men to hold different views and yet agree on some points.

I am greatly pleased to know that there is to be an amplification of

Birmingham University. But the great bulk of our people cannot afford a University education, and that point must be kept in view.

The Professor believes that it is "an equally fine thing for parents and relatives to contrive to send a boy to college instead of putting him to earn wages at the earliest possible moment." But sometimes the former course is not possible. It is not always greed of gain which causes the lad to be sent early to work; it is often necessity. Provision must be made for the technical training of those who cannot afford a University education. Professor Ashley's opinion that it is "a fine thing that a young man engaged during the day, let us say as a draughtsman, should have sufficient ambition and perseverance to attend evening classes," is one which will find ready acceptance, and it is regrettable that in this (and in other references to evening classes) he so quickly proceeded to qualify the remark. Previous speakers have challenged the wisdom of the observation regarding the borrowing of money to pay University fees. Many of us, no doubt, prefer the sound philosophy of Shakespeare—old-fashioned though it be.

> "Neither a borrower nor a lender be!
> For loan oft loses both itself and friend;
> And borrowing dulls the edge of husbandry."

One cannot study well unless he is free from financial embarrassment. I would think more highly of a young man who, rather than stoop to the degradation of debt, cuts his coat according to his cloth, is diligent in his daily duties in a works, and seeks to supplement the practical training and valuable information which can be gathered there by attending evening classes—such as those which have been so splendidly organised in this district under the directorate of Professor Turner.

From observations here and there throughout the paper, one may reasonably come to the conclusion that Professor Ashley is of opinion that there is an insufficiency of instruction at evening classes, and that such training cannot be so satisfactory as a University training. Having had the benefit of four years tuition as a day student at a Technical College, I know the advantages to be derived therefrom. I also know the advantages of évening classes, coupled with the practical experience gained in works, and I should be sorry indeed to see the ladder by which I climbed to the higher stage of education thrown down or neglected.

What can be the meaning or intention of the statement that "so far in England, with all our outcry for higher technical education, we have hardly got beyond the stage of Evening Classes"? That statement is, I think, very severe on the experienced Technical Professors in the several flourishing Colleges in our chief cities. It assumes that the Professors—past and present—have been wanting in alertness.

In the Technical College in Glasgow about 600 day students are in

attendance. Some of the most eminent scientists have been on the staff there, and the present Professors are well known and respected. Large numbers of day students attended the Victoria University Classes in Liverpool, Manchester, and Leeds. When I lived in Leeds I regularly saw troops of day students attending the College. In Sheffield are some splendid institutions, especially the metallurgical one under Professor Arnold. At the Metallurgical Laboratory at the Royal School of Mines in London, 60 day students are in attendance during the session.

Prior to submitting proposals for the enlargement of the scope of the University of Birmingham, a deputation visited some of the educational institutions at home and abroad. It is reported that when the deputation saw the Metallurgical Department of the University College, Sheffield, the opinion was expressed: "We have seen nothing better than this even in America."

In the face of these facts we are surely entitled to some explanation from Professor Ashley regarding that phrase in his paper: "We have hardly got beyond the stage of Evening Classes."

Professor Ashley evidently thinks that we suffer from serious imperfections both in our day and evening classes, and that these are about to be remedied by Birmingham University, which is going to base its methods on American lines. An interesting glimpse of what we may expect from the importation of American education may be obtained from Professor Ashley's paper. The Professor tells us on page 157 that "a Carnegie or a Schwab is an exception which will break all rules; and men like these know how to secure the co-operation—are ready to pay highly for the co-operation—of the most thoroughly trained men they can obtain. When I went over the Homestead Works some two years ago, it was amusing to see how anxious the colleagues of Mr. Schwab were to disabuse my mind of any mistaken notion I might have on the matter, and to point out to me distinguished graduates of Princeton and Columbia at the head of several of their great departments." That is most interesting, especially if read in conjunction with the Professor's belief expressed on page 162 in these words: "I suppose there is hardly a process employed in the Homestead Works which was not derived from English or German practice."

What has become of American originality? What have all the highly-paid technical experts, who have been trained in the much-talked-of American Universities, and sent in such large numbers into the American works, been doing during the last number of years?

I believe that both the day and evening classes in our Technical Colleges and Schools are doing excellent work.

Birmingham University is new and has yet to win its spurs, and much

has to be done ere the efficiency of the best of the technical evening classes in leading centres can be overtaken.

Many in this room have had all their technical training in works and at evening classes, and they are day by day so conducting their works, or the departments under their charge, that they contrive to make a profit even with old plant and under the severe stress of competition with other works at home and abroad.

I most sincerely wish success to the new development at Birmingham University, and I also wish for a continuance of the highest possible efficiency of the evening classes.

The evening classes have produced giants in the realms of industry and commerce. They developed such men as James Beaumont Neilson, the son of a Scottish artisan, who, when a journeyman, entered the evening classes at Anderson's University. His only technical training was obtained at these evening classes, and one outcome was the introduction of the hot-blast for iron smelting, and which is saving such an enormous amount of our precious fuel.

Another of its students was David Livingstone, who utilised "the jaded odds and ends of his working days"—to borrow yet another quotation from Professor Ashley's paper—to the extent of walking eight miles to the evening classes and walking the same distance home to his native village of Blantyre.

There also entered the evening classes at that University an apprentice joiner, by name James Young, who became assistant to that most distinguished chemist, Thomas Graham—afterwards Professor of Chemistry in London and Master of the Mint. Young worked out on a practical scale the process for the extraction of oils from shales, by which he enriched his country by many millions of pounds. And when he had acquired reputation and wealth, he forgot not the "Old Andersonian," but built a new wing to it, endowed the "Young" Chair of Technical Chemistry, and gave liberally to its various schemes.

The London Evening Classes claim a very distinguished student in Sidney Gilchrist Thomas. He was intended for a learned career, but, his father having died during his early youth, young Thomas manfully worked to earn his own living, and took advantage of the educational facilities within his reach and within his means. He it was who solved the problem of dephosphorising steel, and to-day the Thomas-Gilchrist (or Basic) process, as pioneered by him, is of the utmost importance. According to W. T. Jeans, the leading metallurgists at home and abroad were in quest of a practical, paying means of getting rid of that enemy of the steel-maker—phosphorus. A young, unknown man, with no technical training save that which the evening classes gave, bore off the prize.

I repeat that evening classes have produced giants in the realms of industry and commerce, and we owe a deep debt of gratitude to such institutions.

Mr. A. R. Banks: No doubt commercial development is an ideal very earnestly to be desired, and therefore we are all very glad of the paper. There is one passage, however, which seems to me to read a little bit strangely, namely, where the Professor intimates that there is more money made in catching the markets than in technical work carried on in the manufactory. Well that seems to me "rather rough" on the technical man, for unless the article is properly made, it is impossible to sell it.

Mr. Robt. Buchanan: There are only one or two points upon which I should like to comment. First of all, as regards the use of technical education to men who are about to engage in business. There is just a fear that the young men with university training will be a bit above their business. I know of one young man who was undergoing a training preparatory to becoming an engineer. He said to his tutor, "When I go into the shop, I will take care I do not mingle with the common working men." The tutor happened to have had some experience among working men, and he told the student that he himself had worked in the foundry; whereupon that young man had the grace to say, "Well I never did think I was such a cad." A man who has his head screwed on level can certainly get great advantage from technical training, but it all depends upon how he applies it afterwards. As for the information asked for on the forms distributed, I think, as a rule, we British are too self-contained and too conservative. On the other hand, I have heard Mr. Walter Jones mention that he invited a rival manufacturer into his works, although that rival would not admit Mr Jones into his own. The rival afterwards confessed that he was years behind Mr. Jones. Americans are willing to show us their methods, and the man who in the long run learns most is he who is willing to show all he can to his fellows. If we put into Professor Ashley's hands certain broad principles as to trade practices in this district, which we have learnt in our own way, and if he can apply them for the advantage of the young men of this country, then I think such a procedure will be of the greatest advantage to the country at large.

Mr. George Head: I do not wish at all to discuss the Professor's paper; but at one point he says something about shorthand. It should not be crowded into the elementary school course, but students of 12 or 13 ought to take it up. I have found, as a teacher of evening classes for three or four years past, that students who have a knowledge of shorthand get on more rapidly than those who have to write out their notes in longhand. I agree with Mr. Parry that students should be taught how to write business letters, and how to address an envelope.

The Chairman: Now that the University has been established, it is

of the utmost importance that gentlemen like Professor Ashley should come to those who have to fight the battle of industry. The purely commercial man may make a very good seller, but unless the goods which he has to offer are well made, his talents are useless. I have the greatest appreciation for the practical man. At the same time, of course, let him get as much theoretical knowledge as he possibly can. We want the two combined. We cannot all go to the universities; most of us have to fight our way up from the lowest round of the ladder. However clever a man may be, when he is first taken into a works there is always a lot to learn. The best man would be the man who could sandwich his technical training and his theoretical knowledge, first of all in the workshop and then at college. A man who has to manage affairs at headquarters should have practical as well as commercial knowledge. But it is almost impossible to master both. My experience is that a man should devote his attention to the particular science required in his department. An engineer should study all questions relating to engineering, and a blast furnace manager all those relating to blast furnace and foundry practice. It is too much to expect one man to grasp the details of all the various departments in a large undertaking. It has been my lot to "go through the mill" in different shops and to make the most of what theoretical training I was able to get in the evening classes. In a district like this we want to keep our eyes on the smartest boys in the schools. When we see likely material in the schools let us make the most of it. We must also remember that there is not room for a great number of clever men. Taking into consideration all the positions available, it is evident that however well qualified he may be, there are not enough positions to go round. We are delighted to have Professor Ashley among us, and no doubt the hints he will get from the practical men will be of the utmost value to him.

Professor Ashley: I am very glad you did not continue to talk about not wishing to criticise a Professor. The fact is that that sort of thing usually conceals a kind of good-humoured contempt for the Professor. I welcome your keenest criticisms if only you will believe that I am really trying to be practical, and that we at Birmingham are doing the best we can. Those criticisms as to borrowing money are indicative of the customary English state of mind. It is a matter for common sense. I don't advise anybody to go to a money-lender and to sign a contract which is going to hang round his neck like a millstone. In fact, I don't advise purely business-like money loans at all; but I do think there is room for more generosity and more faith and more confidence. I think elder brothers should try to help younger brothers, and prosperous uncles could very frequently help nephews. Men of means in a community, who happen to know and believe in certain boys, could very often help those boys by lending them a little money, making it an obligation of honour for the boys to repay if they could by-and-bye. These men might say, "I will lend you what you

need to enable you to go through college. A few years after you come out of college, before you marry and settle down, you will probably be able to repay me. If your health should break down, of course I shan't expect to be repaid." Such a thing is extremely common in America; and in spite of what we say about debt, such generosity would often be extremely beneficial. It is a very right feeling to have an aversion to borrowing, but we carry that aversion sometimes, I think, a little too far. With regard to evening classes, it took a great deal of courage on my part to say what I did, in the Midlands and in the provinces generally. I attach the highest possible importance to evening classes conducted by County Councils and similar bodies. They have done a remarkably good work. The list of names Mr. Macfarlane has cited is a noble list, of which we in England ought to be proud. If the boy cannot do anything else, by all means let him go to evening classes, and not wait and do nothing, and awaken to ambition only when he is too old. Of course I recognise also that there are higher duties than the cultivation of one's mind, such as duties to parents, aud so forth. Such cases as have been quoted let us thank God for, and by all means let instruction by means of evening classes go on. And yet, and yet—we have perhaps thought too exclusively and too entirely of those men, and by making instruction in the evening so easy, and by throwing all our enthusiasm and our sympathy in that direction, we have failed to suggest to boys that they might do something else. Of course you cannot argue for exceptional cases, but I do think, as a rule, that if a boy is going to give his best powers to the work, on the whole he will get more benefit out of a three years' day course, giving all his mind and strength to it, than by attending evening classes when tired and at the fag-end of the day. That being so, we want to set the notion going that boys could get that kind of thing if they would have a little more pluck and not take the immediately easy thing, and if their friends and relatives would be more liberal. With regard to your sons, it may be perfectly right to put them into business at 17 or 18, but I should like you to say to yourselves, "Am I quite and absolutely certain that I cannot send him to college?" I should like you to think about it carefully. As to day colleges, we in England have done nothing like so much as we ought to have done. What are 60 day students in metallurgy in London, the centre of the Empire? It does not impress me as being at all a large number. Let us be thankful we have even 60, but we ought to have 600. As to secondary education, I quite agree with what has been said as to Grammar Schools. In the past the Grammar Schools have been regarded as old-fashioned institutions, intended only for the professions. I am glad to say that over the larger part of the kingdom that sort of thing has passed away, and most Grammar Schools now give a modern education. Every community ought to have a good, sound secondary school; and if the present schools cannot be reformed, it ought to start a new school of its own.

That is one of the benefits brought within our reach by the Education Bill. I know nothing about Dudley; but every community ought to have a really good secondary school for lads up to 17 or 18, which should give a thorough, straightforward, modern education, including composition and the writing of a sensible business letter. Certainly a boy of 17 ought to be quite capable of writing a good sensible business letter. Mathematics and modern languages ought also to be important parts of the course. The fact is, the teaching of foreign languages in many of our schools is just a pretence, and where it is not, it is often second-rate. The English parent ought to wake up and insist that the modern languages should be taught just as thoroughly as the ancient ones, and even a good deal better.

A vote of thanks was accorded, on the motion of the CHAIRMAN, seconded by Mr. TOY.

PROFESSOR ASHLEY: I thank you all very much. In the first place, don't forget to fill up the forms; and in the second place, invite me here again.

ANNUAL MEETING.

The Annual Meeting was held at the Station Hotel, Dudley, on Saturday, April 25th, 1903.

The President, Mr. Walter Somers, occupied the chair.

The Minutes of the last Meeting were read, adopted, and signed.

The Secretary read the Annual Report of the Council, which was as follows:—

REPORT OF COUNCIL FOR SESSION 1902-1903.

On the 16th July, 1902, a party of about 130 members and friends visited Coventry, arriving there at about 10 a.m. From the station they went to the works of Messrs. Alfred Herbert, Ltd., where they were met by Mr. Oscar Harmer and other officials, and shown through the works. At the conclusion of the inspection of the works, luncheon was served at the King's Head Hotel.

In the afternoon the works of the Daimler Motor Co., Ltd., and the Motor Manufacturing Co., Ltd., were visited and inspected.

Dinner was served at the King's Head Hotel, at 6 p.m., the President's guests being Messrs. Oscar Harmer, P. V. Vernon, and A. E. Marston (of Messrs. A. Herbert, Ltd.), and Messrs. George Iden and W. H. Thomas (of the Motor Manufacturing Co., Ltd.) After the loyal toasts, the President thanked the firms whose works had been thrown open for inspection, for the opportunities offered, and the attention shown to the members during the day. Messrs. O. Harmer and Geo. Iden replied.

The party left Coventry for home at 8·5 p.m.

Seven Ordinary Meetings have been held during the year, at which the following papers have been read:—

18th October, 1902—Address by President on his experiences during a recent visit to Germany.

29th November, 1902—"Some Notes on a Visit to Western Pennsylvania, in the Summer of 1902," by Professor Turner.

13th December, 1902—"Lessons for the British Iron Trade, from American Experience," by Mr. J. S. Jeans.

17th January, 1903—"The Utilization of Pit Tips for the Growing of Pit Timber," by Mr. Herbert Stone.

7th March, 1903—"On Gas and some other Heat Engines," by Mr. John W. Hall.

21st March, 1903—"The Modern Continuous Rolling Mill," by Mr. Axel Sahlin.

4th April, 1903—"The Universities and Business," by Professor W. J. Ashley.

All the meetings have been well attended, and the papers (some of which were well illustrated) have aroused considerable discussion and interest in this and other districts. Several of the papers are now out of print.

Mr. Stone's paper appealed to a larger circle than those engaged in mining and metallurgical pursuits, and the movement for reafforesting the Midlands, which has resulted in the formation of a society, having its headquarters in Birmingham, is the direct result of the reading and discussion of Mr. Stone's paper at this Institute.

The following members have joined during the year:—

Honorary:—Isaiah Oldbury (Mayor of Wednesbury).

Ordinary:—Messrs. W. K. Broughton, W. H. Danks, J. C. Davies, J. H. G. Davis, Jno. Ellis, H. L. Evers, W. J. Flavell, B. L. Green, J. G. Hadley, Geo. H. Head, Walter Macfarlane, H. G Mantle, A. E. Nurse, W. J. Onions, E. A. Screen, and J. W. Shenton.

The following have left during the year:—

Honorary:—Messrs. J. W. Langham and H. W. Punnett.

Ordinary:—Messrs. T. Broadbent, T. B. Browett, E. A. Davies, Geo. Glaze, W. L. Green, R. Hedley, W. Nock, jun., T. Pasfield, W. A. Robbins, W. H. S. Shakell, A. L. Scotson, B. Simpson, G. E. Vaughan, and A. Wassell.

Died:—J. J. Chambers, David Crofts, and John Robinson.

The present state of membership is:—

	Honorary.		Ordinary.	
No. of Members in April, 1902 ...		55		180
Joined during the year		1		16
		56		196
Died	...		3	
Left	...		1	
Resigned	1		7	
Struck off	1		6	
	—	2	—	17
No. of Members in April, 1903 ...		54		179

Total number in 1902	...	235
,, ,, 1903	...	233
Decrease	...	2

The finances are in a satisfactory condition. The balance sheet shows an excess of expenditure over income of £6 5s. 4d. This, however, is due to the exceptional character of the papers printed, and to the cost of completing the two volumes of "Proceedings" which have been issued during the Session.

It is recommended that the members visit the Great Western Railway Co.'s Works at Swindon during the summer, the authorities there having expressed their willingness to render the visit as successful as possible.

For the Council,

W. SOMERS, President.

WILLIAM H. CARDER, Secretary.

Dudley, 25th April, 1903.

Mr. J. PIPER read the audited Balance Sheet for the year ending 31st December, 1902.

(The Balance Sheet appears on Page 188.)

Mr. Moses Millard, in criticising the report, went into the figures of membership, and expressed regret that numerically the Institute did not make that progress which some time ago he hoped it would. The influx of new members only just made up for the loss through deaths and withdrawals. He thought it was a matter worth serious consideration. The report in all other respects he regarded as good.

The Chairman asked for any suggestions on the lines of Mr. Millard's remarks. Undoubtedly the matter was one worth consideration, though he was inclined to think there was not very much wrong; if, however, they could do better, they ought to do it. It might be well for each member to formulate some suggestions, and present them for discussion at some subsequent meeting.

On the motion of the President, seconded by Mr. W. Brooks (vice-resident), it was resolved that the Report and Balance Sheet be received id passed, and printed in the Proceedings for the Session.

Mr. W. Brooks proposed, and Mr. J. W. Hall seconded, the re-ection of Mr. Walter Somers as President of the Institute during the isuing year. The motion was supported by Messrs. Millard, Parry, id H. Pilkington, and carried with acclamation.

Mr. Somers, in acknowledging the appointment, expressed himself nsible of the honour conferred by his election three years in succession. iere was, he said, ample scope for such an institution in a district like uth Staffordshire, and it would be his earnest endeavour, during the suing twelve months, to promote its objects and increase its member-ip. He proposed the re-election of Mr. Brooks to the position of ce-president. Mr. Millard seconded and Mr. Parry supported the otion, which was carried unanimously. Mr. Brooks briefly acknow-lged the compliment.

On the motion of the President, seconded by Mr. Parry, Mr. mes Piper was re-elected treasurer.

On the proposition of Mr. H. Pilkington, seconded by Mr. Walter nes, Mr. W. H. Carder was re-elected secretary.

The Secretary then pointed out that by reason of a resignation and n-attendances there were three vacancies on the Council, and he bmitted the names of Messrs. H. Le Neve Foster, F. E. Nurse, and illiam Somers, to fill the vacancies; the remaining members being en for re-election. On a motion from the chair, seconded by :. S. Westwood, the eligible members of the Council were re-elected, d the three gentlemen named were added to their number, the uncil for the ensuing year consisting of Messrs. T. Ashton, John te, Joseph Brown, Alfred Cookson, James Donechay, David Evans, Le Neve Foster, W. J. Foster, Jno. W. Hall, Walter Jones, Richard thgoe, Moses Millard, Frank East Nurse, Henry Parry, Harry

Silvester, William Somers, L. D. Thomas, Harry B. Toy, A. E. Tucker, Thomas Turner, and William Yeomans.

The Secretary announced that the Institute had an invitation to make their Annual Excursion to the Swindon Works of the Great Western Railway Company.

On the motion of Mr. W. Brooks, seconded by Mr. J. Piper, it was resolved that the Excursion should take place on July 1st, and should be to the Swindon Works; and on the motion of Mr. C. E. Bloomer, seconded by Mr. J. H. Whittaker, the Council was empowered to make the necessary arrangements.

THE ANNUAL DINNER.

The Annual Dinner was subsequently held, the chair and vice-chair being occupied respectively by the newly-re-elected President and Vice-President. The guests were Mr. Ebenezer Parkes, M.P. (Chairman of the British Iron Trade Association), Mr. John Hughes (Mayor of Dudley), and Mr. Geo. Bean, J.P. Letters of apology for absence were received from the Presidents of The West of Scotland Iron and Steel Institute, The Birmingham Society of Mechanical Engineers, and The Birmingham Society of Civil Engineers; Mr. W. Belcher, and Mr. Gilbert H. Claughton.

After the loyal toasts had been suitably received and honoured,

The toast of "The Iron, Steel, and Coal Trades of Staffordshire" was proposed by Councillor George Bean, J.P. In the course of a vigorous speech, that gentleman gave a rapid survey of the iron and coal trades of Staffordshire during the past sixty years. At the present time those trades were, he said, passing through what was known as a cycle of trade depression. It was not the first time some of them had passed through such a period. Some of them could look back over a period full of history and teeming with personal reminiscences. History was a dry subject, and he should, therefore, not deal much with it; but reminiscences would enable them to appreciate the matters that appertained to the present. Some of them were able to go back to "the forties," when the iron trade was not what it is to-day. He meant unfortunately for those of to-day. The industry of iron-making as a commercial pursuit had reached its zenith in the forties; then for many years the people engaged in that industry enjoyed prosperity, and some became millionaires. Then came the disastrous strike of 1864. He was informed that about that year there were within a radius of two miles of Dudley (which, by the way, was a very flourishing town) 160 blast furnaces in actual existence, and that out of these 120 were in operation. During that fearful war between capital and labour the masters could not trust their men, and the men sought to destroy their masters. The men attempted to blow up the house then occupied by their present Mayor. The masters came out of the struggle entirely

successful, but with depleted pockets and lowered prestige. But that was not all. He would beg that men who were leaders of our working classes, especially in matters of industrial struggles, would take into consideration the sequel to these duels between capital and labour. When the men returned to work, and trade came back and furnaces were relighted, instead of 160 blast furnaces not more than 60 resumed operations. From that moment the disastrous consequences of that war began to be felt. Other iron-making and coal-producing districts were opened up, and competition with this district was felt even to-day from places in Cumberland and Northamptonshire that did not previously exist as competitors.

The strike of '74 made matters no better, and that was followed by the strike of '84, and to-day the pig-iron industry of the district was so crippled, and was in such a state of decay, that instead of 120 blast furnaces there were now only about 20 in operation. The moral of this was that there should be no divorce between labour and capital. The two were twin sisters, and should go hand in hand. The man was dependent upon his master, and the master upon his man. He would ask their attention for a few moments to a particular phase of the industry. A very serious change was now coming over the iron trade, namely, the development of that serious rival—steel. It was impossible for them to see the marvellous developments at Spring Vale and Round Oak without observing that steel was raising its defiant head. He believed that steel was the metal of the future. In the closing of the works at Corngreaves, Chillington, Wednesbury Oak, and other works of more or less importance, they could read the lesson that iron was giving way to steel. Those present who were so closely allied with the coal and iron and steel trades would know whether he was right, and if not, no doubt Mr. Parkes, when he spoke later on, would correct him. This alteration in an industry led to other considerations. Great Britain was face to face with a serious problem—the competition of the United States, Germany, and some of the minor European nations. He wanted to impress upon his hearers that although, as a nation, we might think we were up to date, yet England was, by virtue of her isolated position and physical conditions, in a vastly backward position compared with the United States. They had heard a good deal about American trusts, and he had been considering what he would do, if he were in the iron and steel trades, to meet the effects of the competition from the United States. It was a grave question, and one which every thinking man would have to face. He had come to the conclusion that the only way was to fight the Americans with their own weapons in the matter of large combinations. Combination made the Americans masters of vast sums of money as capital, and enabled them to use the most up-to-date machinery. Instead of the old flint weapon they could, so to speak, employ the modern breech loader, with which they could bring down their birds much more quickly and surely than the British manufacturer

could with the old weapon. He was not advocating combinations based on unsound commercial principles—watered undertakings with a great amount of goodwill—but combinations of concerns having similar interests, and with assets worth 20s in the pound, and which were absolutely sound. Given this capital, they could root up old machinery and employ the most modern appliances. They had heard of a firm in that district who had recently replaced its means of power by Mond gas, and in that way the costs were lowered, profits were greater, and risks were proportionately reduced. It was only by such a combination as he had foreshadowed that, in his opinion, we could hope to satisfactorily meet the competition of the United States. We should, however, have to give the Americans a long leg, for we had not got a grandmotherly Government that would protect industries by tariffs and in other ways; but the methods of manufacture might be brought so up to date, and the cost of production so cheapened, as to render it impossible for the Americans to overtake them. Another very serious feature to be considered was, that we had not the natural resources that they had in the United States. Therefore, he would advocate the formation of such combinations as would link together the ore deposits, the coal deposits, and the ironworks, so as to obtain control of the raw materials, and render the combination independent of speculators on the Stock Exchange, who rigged the market and were the natural enemies of industrial enterprise. He would now pass on to the coal supply. They could not do without coal, and the expansion of the coalfields was a very important matter for the country, and especially for South Staffordshire. He was pleased to welcome there to-night his old and sincere friend, the Mayor of Dudley. His Worship deserved the thanks of all industrial men in South Staffordshire for the plucky manner in which he had tackled the exploration of the thick seams of coal at Baggeridge Wood, and for the success that had attended his efforts. As to the trade of Dudley, Mr. Bean quoted figures furnished him by the Postmaster of Dudley, which showed a marked increase of business, not only in the postal and telegraph departments, but also in the money order and savings bank departments. In the last named, £6,900 was deposited last year, whilst only £3,200 was withdrawn. Such figures, he held, showed the wonderful vitality of that good old Black Country town. In giving them the toast entrusted to him, he wished to couple with it the names of Mr. Ebenezer Parkes, M.P., and Mr. John Hughes (the Mayor).

Mr. Ebenezer Parkes, M.P., Chairman of the British Iron Trade Association, responded. He said he felt sure they had all been very much interested in the able speech they had just listened to; but he thought that perhaps Mr. Bean took rather too gloomy a view of the condition of the iron trade in South Staffordshire—the figures he had quoted as to Dudley in the conclusion of his speech, went to give an answer to the first part of the speech. No doubt steel was pushing iron

out, but so far as South Staffordshire was concerned it would be a very slow process, for there was, and he thought there always would be, a use for iron in the manufacture of articles for which that metal was particularly constituted. They could manufacture steel as well as iron in that district. The figures furnished by the Midland Iron Trade Wages Board of the last ascertained bi-monthly production of the twelve selected firms showed that there was an increase over the production of twelve months ago. That showed there was plenty of vitality in the iron trade of South Staffordshire He did not think they ought to compare the nnmber of blast furnaces now with those working thirty or forty years ago, for the modern blast furnace turned out two or three times as much as an old one. Moreover, if they added to the output of iron the amount of steel that was being produced, the district was not as far behind as might appear from the remarks of the last speaker. As to combination, he did not know whether they had the same chances in South Staffordshire as in some other districts, but there was a probability of a combination such as had been indicated by Mr. Bean taking place somewhere in the Midland district with some success. And he thought that it would have every chance of success if it controlled the products used from the ore to the finished article. He was told that there were deposits of ore in the Midland district containing a high percentage of iron which would pay an enterprising combination to acquire and utilise. He would like to see South Staffordshire producing steel in larger quantity. His hearers knew only too well that there was a vast quantity of steel brought into the district in the shape of bars, billets, and ingots from South Wales, Germany, and Belgium. Why could they not be produced in or near South Staffordshire, and consumers thus save in carriage alone from 12s. to 14s. a ton? If they could produce this raw material there would be greater hope for this district. That time had, however, not yet arrived, and until it did, they could only get cheap steel when the Germans and Belgians had not plenty of orders. He was told that in America some private concerns are much better situated for production and for withstanding fierce competition when it came, than the trust concerns. When he was in that country there seemed to be chances in favour of some of the private concerns against the combinations. Two things operated against combinations. The first was inflated capital—they were generally put on the market at an enormous premium, and then foisted upon a more or less confiding public. Of course, at present, trusts occupied a very strong position, but they had not yet been tested. The second thing against them was the large salaries paid for management. He did not think that combination alone would settle the question of American competition in this country. He did not think America could have done what it had were it not for its protective tariffs. A writer criticising some of his (Mr. Parkes's) recent remarks had referred to the subject of tariffs. This critic had said it was not

their advantages as to machinery, or trusts, or matters of that kind, and gave as the reason why they are able to develop their business and to compete successfully in other countries, that they make the home consumer pay 40 per cent. more than he ought to pay for the purpose of capturing a market in any and every part of the earth. He (Mr. Parkes) did not say that England ought to follow such a line; but he did say that that was the reason why the Germans and Belgians were able to compete with the British manufacturer. There had never been such a spirit of enterprise and inquiry, and such a desire on the part of masters and managers to improve their works, as in the last few years. That, he thought, was a very hopeful sign. But they had not yet produced an up-to-date manager of a works. He implied no reflection upon the managers of South Staffordshire, certainly not upon the forge managers, who could not be beaten in any district in this country. They wanted managers able to deal with statistics, men who thoroughly understood chemistry, and with a complete knowledge of commercial matters. Such men were to be found in the well educated over-managers of the works in America. Now that they had in their midst technical institutes, scientific colleges, and the University of Birmingham, it would be a great shame if they could not produce the kind of man he referred to. There was one word which really focussed what he wanted to say, and that was "Economy." Economy should be written upon every piece of machinery in the works. It was a deplorable fact that many ironmasters in South Staffordshire—men of honesty, integrity, and uprightness—get into the Bankruptcy Court because of the enormous waste in their works. They did not sufficiently understand the principles of economy. With regard to their workmen, there were two evils from which they suffered—perhaps not more than in other districts—he referred to drinking and gambling. Sometimes they were victims of circumstances, and it was deplorable that there were no means by which workmen could make profitable use of their leisure hours. Very often the men had only two alternatives, either a miserable home or the public-house. The masters had a great problem to solve in making the men sober, steady, and thrifty, and in securing for them better means of using their leisure. Speaking of the community of the interests of capital and labour, he urged the importance of closer co-operation between masters, managers, and men. The remarks of Mr. Bean on this head were well worth attention. He believed the day was far distant when the prognostication that South Staffordshire was sinking into oblivion would come to pass.

The Mayor of Dudley (Mr. J. Hughes) also responded to the toast. As indicating the progress made in the coal trade, he pointed out that at Sandwell Colliery the upcast shaft was 11ft. in diameter, and the drawing shaft 16ft. They had ordered improved machinery, including compound engines, which would lift coal at the rate of sixty miles an hour. They had sufficient coal to last for sixty years with an output of

2,000 tons a day. At the new sinking at Baggeridge Wood they anticipated being able to raise 3,000 tons a day for one hundred years. There was coal enough to keep the hearts of his hearers light for a century. If a combination was formed for the benefit of the iron and coal trades of the district, perhaps it might be worth while to take the two undertakings he had mentioned into it, though they did not particularly want to be absorbed. The Mayor then proposed the toast of "The Institute." He remarked upon its existence of nearly forty years, its membership, and upon the papers read during the past year. Referring to the paper read by Mr. Stone, Mr. Hughes remarked that as to the reafforesting of the pit mounds in Belgium, they were not in that country troubled with disintegration, nor with fires due to spontaneous combustion. As to the ironworks, he remarked that in South Staffordshire they had undoubtedly the best materials in the world, and they made the best pig iron. America, Russia, and Germany all came to buy that pig iron for certain of their manufactures. He thought there was a great deal in what Mr. Parkes had said about the waste in the works. That matter was worthy of their careful consideration. As to improved machinery, he might tell them that in the mines they were putting down appliances of the most modern type. He wished the Institute continued success .

The President, in responding to the toast said they were very proud of their Institute, and they believed it was an important one as regarded masters and men and works management. It required, he could assure them, a great amount of tact on the part of the manager to run a works successfully. They had heard a great deal about America and Germany; but if some of the managers from those countries were brought into the works of that district, they would make some of the concerns bankrupt in twelve months. A walk through some of the Staffordshire works was enough to make one wonder how the work was got out at all. There had not been the disposition amongst masters to make the necessary improvements. He lately saw a blast furnace turning out 1,800 to 1,900 tons a week with scarcely any men. Mr. Parkes had talked to them about economy, he (the President) thought that could be readily brought about by the works being equipped with machinery to do the work in an economical way. They were exercising more economy in the works to-day in every way than had been done in the past. Some few masters were putting down new machinery, and if other masters did not follow in their wake, they would be left behind in the race. He had seen nothing abroad but what could be done in this country. Staffordshire was greatly handicapped, and he urged upon their attention the value of improved waterways. The railway companies charged 12s. 6d. to 15s. per ton to take iron and raw materials, and up to £1 per ton for some other articles, to the coast, while German manufacturers could send right into this country for less. They could not be expected to stand against that sort of competition. The sort of

combination that was wanted in South Staffordshire more than anything else was one which would secure a new waterway from Liverpool to London.

Mr. WALTER MACFARLANE, F.I.C., proposed "The Honorary Members," and in doing so expressed regret at the absence of Professor Turner, who took a warm interest in the Institute.

Following the remarks of the President, he pointed out that the river Clyde was at Glasgow harbour very largely an artificial waterway. The river had been widened and deepened by constant dredging—the widening and deepening keeping pace with the growth in the number and size of the ships—and had been effected from the income arising from moderate dues. The great prosperity of the Clyde district arose, in large measure, from the facilities provided by the waterway.

On the Clyde they launch, on an average, a new-built ship for every working day of an ordinary year. When we hear so much of the industrial progress of Germany and America, it might perhaps be some satisfaction to remember that on that one British river alone the tonnage of ships launched last year was within some 70,000 tons of the ship-building (for the same period) of the whole of the German Empire and the whole of the United Sates of America put together.

Another point had been touched on—that of technical training. It would interest them to know that in that branch which had an intimate connection with the Institute—the subject of metallurgy—Staffordshire had taken a high position. Government examinations were annually held in almost every metallurgical centre in the kingdom, and the Honours results might be taken as a fair test of the work done. The results of that test showed that in metallurgy Staffordshire stood, as one of their Mayors had said, "easily first in the whole land." Passing in the final stage of Honours meant successfully undergoing a searching examination in one's own town and a three days' examination in Practical Metallurgy at the Royal School of Mines, London. Three years ago the only one in the kingdom who passed the final Honours examination was a Staffordshire student. Two years ago one Birmingham student passed and two Staffordshire students passed. Last year one student from Mid-Lancashire was successful, and five from Staffordshire passed. The only one who in recent years was awarded a medal for metallurgy was a Staffordshire student—one of the younger members of the Institute. He therefore did not think there was much need for dismal looks in the matter of the technical training of our young men.

Then as to new plant. That was everywhere being quietly and quickly installed in the leading iron and steel works in other districts as well as in the Midlands. And so long as certain "Honorary Members" were with us, we might well have confidence. He had pleasure in submitting the toast, which he coupled with the name of their esteemed friend, Mr. John Fellows.

Mr. Jno. Fellows, in replying, referred to the wide range of papers dealt with in the course of a year at the Institute meetings, and upon their usefulness to the members.

Mr. H. Parry, in felicitous terms, proposed "The Vice-President," to which Mr. W. Brooks responded.

Mr. H. B. Toy proposed "The Past Presidents." He remarked that much had been said about German competition. When in Germany last year he was very much surprised to find on the bed-plates of many of the engines in various works the names of English engineers. The competition from America arose largely from their natural advantages. But America's progress was also due to the ability of Scotchmen, Englishmen, and Welshmen—Mr. Carnegie was a Scotchman, Mr. Morgan was a Welshman, and Mr. Talbot was a Brierley-Hill man.

Mr. Herbert Pilkington replied. He said that he was much impressed with what he had heard about foreign competition. He had wandered around the European Continent and America, and he was going to the latter country again shortly to see what strides they had made. There must be some reason why the best ability of this country had gone out there. He agreed very much with what Mr. Macfarlane said. Much was talked about technical education and the like, but there were such things as the old natural faculties which came out on top, whatever education was given them. There was a lot of education wanted in the direction of the hands that held the money and had control of the works. The Labour Commission seemed to him to adopt the same view. It was harder work managing the masters than it was managing the men. He had noticed that the young men who came to the works either as apprentices or as students, did not take that interest in their duties that the young men in Germany did. He considered that some of our technical education schemes wanted re-organizing on a better business basis.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

BALANCE SHEET,

FOR YEAR ENDING 31st DECEMBER, 1902.

Dr.

	£	s.	d.
To Balance brought forward	126	5	8
„ Subscriptions	127	14	6
„ Books and Papers Sold	13	13	1
„ Interest on Invested Funds		14	0
„ Balance of Excursion Account ...		11	6
	£268	18	9

Cr.

	£	s.	d.
By Expenses at Annual Meeting ...	7	13	0
„ Printing and Stationery	80	9	1
„ Shorthand Notes	15	10	2
„ Postages and Telegrams...	14	5	11
„ Carriage and Sundry Expenses ...	3	0	3
„ Rent...	8	0	0
„ Secretary's Honorarium	20	0	0
	148	18	5
Invested at 2½ per cent., £29 7 3; In Treasurer's hands, £90 13 1	120	0	4
	£268	18	9

Examined with Vouchers and found correct this 15th day of April, 1903.

RICHARD ROUND,
JAMES RAYBOULD, } AUDITORS.

VISIT TO SWINDON.

On Wednesday, the 1st July, 1903, a party of 164 members and friends travelled by special train to the Great Western Railway Co.'s Works at Swindon. The train was drawn up at a temporary platform which had been erected in the works, and the party were welcomed by Mr. G. J. Churchward (Chief Engineer) and members of his staff, and conducted to the adjoining Drill Hall, which had been placed at their disposal for the day, where Luncheon wasserved.

At two p.m. the party began a tour of the works under the guidance of Mr. Churchward and the chief officials of the various departments, and every facility was given the members to study the machinery and appliances in operation.

Shortly after five p.m. Dinner was served in the Drill Hall. The President presided, and had as guests the chief officials of the G. W. R. Company. After the loyal toasts, THE PRESIDENT proposed "The Great Western Railway Company," and thanked Mr. Churchward and his staff for their courtesy and kindness to the members during the day. Mr. CHURCHYARD responded, and alluded to the friendly trial of a French locomotive which would shortly take place over the Great Western line, and concluded by proposing "The Institute," to which THE PRESIDENT responded.

The party left Swindon at seven p.m.

The following particulars (together with a plan of the Swindon Works) were supplied to each member :—

The old town of Swindon is mentioned in Doomsday Book, and therefore dates back some eight centuries. It was of some note as an ancient market town, and attained some prosperity during the old coaching days, but up to the time of the selection of the place by the Great Western Railway Company as a central Locomotive depôt, the district now known as New Swindon, Gorse Hill, and Even Swindon was purely agricultural.

In 1842 the construction of the Locomotive Works was commenced; by the end of the year 1846 the population of the district, exclusive of the old town, amounted to 2,338, the increase during the year 1846 having been 732.

As will be seen from the following figures, taken from the census returns, the population has since rapidly increased. It is still increasing, and at the present time is estimated at about 46,000.

The census returns for Swindon and New Swindon show the following figures :—

	Total Population.
1841	2,459
1851	4,876
1861	6,856
1871	11,720
1881	19,904
1891	32,840
1901	44,996

In 1861, the Rolling Mills for the manufacture of rails were erected. From the year 1875, the quantity of rails manufactured was gradually diminished, the last lot having been rolled in steel in 1878. The Mills have since been used for the manufacture of merchant iron, the average turn-out being from 160 to 200 tons per week.

After the amalgamation of the West Midland Company with the Great Western Railway Company in 1862, it was decided by the Directors that a Central Works for the construction of carriages and wagons should be provided. Some delay occurred in deciding upon the most suitable site for these Works, Oxford being considered to offer some advantages as a centre for the work of this department. The ultimate decision was to erect the Works at Swindon, and they were accordingly commenced in 1868, enlargements having been made from time to time to meet the increasing requirements.

In 1873-4 new Foundries were built, and other considerable additions made to the Locomotive Works.

In 1902 a large Erecting and Machine Shop was constructed, the dimensions being 486ft. by 480ft. The traversing tables and overhead cranes, as well as the machinery used, are electrically driven. Power is provided by three sets of vertical gas engines, direct coupled to electric generators working at 250 volts.

The total area occupied by the Works and Yards is 254 acres.

In addition to the construction of the locomotives, carriages, and wagons required for the service of the Company, a great variety of other work is taken in hand, Nearly 400 tons of chairs per week are cast for the Permanent Way Department; large quantities of castings are made for the Signal Department; and a considerable staff is occupied in the construction and repairs of Station furniture and fittings. The heavy repairs to the pumping machinery in use at the Severn Tunnel, and the hydraulic machinery in use at the various Docks and Stations of the Company, are also carried out here.

The carriage stock of the Company is fitted with oil-gas lamps, and is also being fitted with steam heating apparatus, almost the whole of this work being done at Swindon.

.t the time of the change of gauge in May, 1892, with the eption of a few hundred wagons which were taken in at the lgwater workshops, the whole of the broad gauge rolling stock was ught to Swindon to be converted or broken up. Thirteen miles of itional sidings were laid to receive this stock. The total number of ıd gauge locomotives was 195; of these, 130 had been so constructed they were readily convertible to narrow gauge. There were also passenger train vehicles, and upwards of 3,400 wagons and s, a large proportion of which had also been constructed with view to conversion. This was especially the case with a ıber of the eight-wheeled carriages, which required only the nging of the bogies and the alteration of the foot boards to transform n from broad to narrow gauge. On one occasion, 25 coaches were onverted in 6¼ hours by means of specially constructed hydraulic lifts.

'he total number of hands employed in the Locomotive Department ıt this date, May, 1903, 8,268, and in the Carriage and Wagon artment 4,803, making a total of 13,071. In addition to these, ut 710 men are employed in the Traffic, Stores, and Permanent Departments of the Company at Swindon.

'he Rolling Stock owned by the Company as on 31st December, 2, was as follows:—

Loco. Engines	2,787
Carriages, Vans, &c.	7,087
Goods Vehicles	64,143

ı addition to these the Company owns the undermentioned Road icles:—

Omnibuses	26
Parcels Carts, &c.	166
Goods Vehicles, Vans, Lorries, &c. ...	2 025

RULES.

REGISTERED No. 943, WORC.

1.—The Society shall be designated "The Staffordshire Iron and Steel Institute." Its registered office is in England, and is at The Institute, Wolverhampton Street, Dudley, in the County of Worcester. In the event of any change in the situation of the registered office, notice of such change shall be sent within fourteen days thereafter to the Registrar, in the form prescribed by the Treasury Regulations in that behalf.

2.—This Society is subject to the provisions of the Friendly Societies' Act, 1875, except so much thereof as relates to dividing societies (section 11, sub-section 4); the certification of annuities (section 11, sub-section 5); appeals from a refusal to register a society or any amendment of the rules thereof (section 11, sub-sections 8 and 9, and section 13, sub-section 3); or from cancelling or suspension of registry (section 12, sub-section 4 and part of sub-section 5); quinquennial returns and valuations (section 14, sub-section 1, *ef*); certificates of death (section 14, sub-section 2, and section 15, sub-section 9); exemption from stamp duty (section 15, sub-section 2); nomination and distribution (section 15, sub-sections 3, 4, and 5); priority on death, bankruptcy, &c., of officers (section 15, sub-section 7); copyholds (section 16, sub-section 6); loans to members (section 18); the accumulation of surplus of contributions for members' use (section 19); so much of section 22 as relates to the reference of a dispute to the Chief or any other Registrar; the amalgamation, transfer of engagements, and dissolution of Friendly Societies (section 24, priviso to sub-section 8, and section 25, sub-section 1, *c*, and sub-section 7); militiamen and volunteers (section 26); the limitation of benefits (section 27); payments on the death of children (section 28); societies receiving contributions by collections (section 30); cattle insurance and certain other societies (section 31); and the four last heads of Schedule II.

3.—The objects of the Institute are:—To promote the intellectual welfare of its members by periodical meetings for reading and discussing scientific papers on subjects connected with the Iron and Steel Trades, and such other matters as may be considered within the scope of the special authority of 3rd July, 1878 ("The Promotion of Literature, Science, and Fine Arts"). The expenses incurred in carrying out the above objects shall be provided by the subscription of Life and

Honorary Members, the entrance fees and periodical contributions of Ordinary Members, and from interest upon any accumulated capital.

CONSTITUTION.

4.—The Institute shall consist of Life, Honorary, and Ordinary Members, who shall be more than twenty-one years of age, and shall be either owners, managers, assistant managers, and other officials of iron and steel works, mechanical or mining engineers, analytical chemists, draughtsmen, or persons of scientific attainments in metallurgy, or specially connected with the application of iron and steel.

HONORARY MEMBERS.

5.—Any person connected with the Iron and Steel Trades may, on the invitation of the Secretary or any other officer, become an Honorary Member of the Institute, on payment of One Guinea yearly to its funds, such payment to entitle him to receive invitations to all meetings of the Institute, and copies of all its publications. Any Honorary Member may become a Hon. Life Member by the payment of Ten Guineas.

ELECTION OF ORDINARY MEMBERS.

6.—Any person desirous of becoming an Ordinary Member of the Institute must be proposed and seconded, as provided by Form A in the Appendix.

7.—The election shall take place at an ordinary meeting; a two-thirds majority of the members present being necessary for election.

8.—When the proposed candidate is elected, the Secretary shall give him notice thereof, according to Form B; but his name shall not be added to the list of members of the Institute until he shall have paid his entrance fee and first annual subscription, and signed Form C in the Appendix.

9.—In the case of non-election, no mention thereof shall be made in the minutes, nor any notice be given to the unsuccessful candidate.

SUBSCRIPTIONS.

10.—The Subscription for an Honorary Member shall be One Guinea per annum, and for an Honorary Life Member Ten Guineas, as provided by Rule 5. Each Ordinary Member shall pay an entrance fee of Two Shillings and Sixpence and an annual subscription of Ten Shillings and Sixpence; or he may become an ordinary Life Member by the payment of Five Guineas. All annual subscriptions shall be payable in advance, and shall be due on the First day of January in each year.

11.—Any member whose subscriptions shall be two years in arrear shall be thereby disqualified, and the Council, after having given due notice, in the Form D in the Appendix, shall remove his name from the list of members, unless satisfactory reasons are given to the contrary.

OFFICERS.

12.—The officers of the Institute shall consist of a President, a Vice-president, Twenty-one Members of Council, Three Trustees, a Treasurer, and a Secretary, who shall be elected at the annual meeting by show of hands. The President, Vice-president, Treasurer, and Secretary shall be *ex-officio* members of the Committee of Management, herein termed Council. Officers may be removed by a special general meeting.

13—In addition to the *ex-officio* members, the Council shall consist of Twenty-one Members, all of whom shall retire annually, but shall be eligible for re-election, with the exception of those who have not attended any of the Council meetings called during the year for which they have been elected.

14.—The Council shall meet as often as the business of the Institute requires; seven to form a quorum. Such meeting to be called by the Secretary, of which seven clear days' notice shall be given.

15.—The Council shall appoint from its own body two Committees, one to be called the Finance Committee, which shall advise the Council on matters relating to the receipts and expenditure of the Institute; and the other to be called the Publication Committee, which shall arrange for suitable papers to be read at the meetings of the Institute, and shall undertake the revision of all printed transactions. The Council shall provide the Secretary with a sufficient number of copies of the Rules to enable him to deliver to any person on demand a copy of such Rules, on payment of a sum not exceeding One Shilling; and it shall be the duty of the Secretary to deliver such copies accordingly.

DUTIES OF OFFICERS.

16.—The President shall be chairman at all meetings at which he shall be present, and in his absence the Vice-president. In the absence of the Vice-president, the members shall elect a chairman for that meeting.

17.—The Treasurer shall hold in trust the uninvested funds of the Institute, which shall be deposited at a bank approved by the Council; he shall receive from the Secretary all amounts paid by way of subscription, contribution, or payment; and shall pay all accounts that are properly certified as correct by the President and Secretary. He shall keep proper books of account, and shall submit them once a year, or oftener if required by the Council, to the Auditors appointed, and shall supply the Secretary with a duplicate copy of his balance sheet.

18.—The Secretary shall attend all meetings, carry on the general business and correspondence of the Institute, arrange meetings for the reading of papers and for other purposes, and keep minutes of all proceedings, which shall be authenticated by the signature of the Chairman. He shall collect all subscriptions and pay the same to the

Treasurer, and shall prepare and send the Returns required by the Friendly Societies' Acts and the Treasury Regulations to be sent to the Registrar. He shall be paid an honorarium on March 25th in each year, in addition to any sums he may expend on behalf of the Institute for postages, stationery, printing, or travelling expenses.

19.—The Trustees, each of whom must be a householder, and in whose names the properties and surplus funds of the Institute shall be invested, shall continue in office during the pleasure of the Institute, and in the event of any of them dying, resigning, or being removed from office, another or others shall be elected at the next general meeting of the Institute. A copy of every resolution appointing a Trustee shall be sent to the Registrar within fourteen days after the date of the meeting at which such resolution was passed, in the form prescribed by the Treasury Regulations in that behalf.

MEETINGS.

20.—The annual meeting shall be held in April in each year.

21.—General meetings shall be held as often as business requires. The place of such meetings to be decided at the previous annual meeting.

22.—The President or the Council, in case he or they at any time think it necessary, or the President, on the requisition of six members, may convene a special general meeting of the Institute, for the consideration of any subject requiring the immedtate attention of members. The business of such meeting shall be confined to the special subjects named in the notice convening the same.

23.—All members shall have at least six clear days' notice of, and be entitled to attend, each meeting of the Institute, and to receive copies of the Institute's publications gratuitously.

24.—No alterations of the Rules shall be made except at a general meeting, and four weeks' notice in writing must be given to the Secretary of any proposed alterations. No amendment of Rules is valid until registered.

AUDITORS.

25.—The accounts, together with a general statement of the same and all necessary vouchers, up to the 31st December then last, shall be submitted once in every year to two auditors, appointed by the members at the general meeting preceding each annual meeting, who shall lay before every such meeting a balance sheet (which either may or may not be identical with the annual return, but must not be in contradiction to the same), showing the receipts and expenditure, funds and effects of the Institute, together with a statement of the affairs of the Institute since the last meeting, and of their then condition. Such Auditors shall have access to all the books and accounts of the Institute, and shall examine every balance sheet and annual return of the receipts and expenditure, funds and effects of the Institute, and shall verify the same with the accounts and vouchers relating thereto, and shall either sign the

same as found by them to be correct, duly vouched, and in accordance with law; or shall specially report to the meeting of the Society before which the same is laid in what respects they find it incorrect, unvouched, or not in accordance with law; and the balance sheet or report shall be published in the *Proceedings* of the Institute.

COMMUNICATIONS OF MEMBERS AND OTHERS.

26.—All communications shall be submitted to the Council, and after their approval, shall be read at the general meetings. All communications shall be the property of the Institute, and shall be published only in the *Proceedings* of the Institute, or by the authority of the Council.

PROPERTY OF THE INSTITUTE.

27.—All books, communications, drawings, and the like shall be accessible to all the members. The Council shall have power to deposit the same in such place or places as may be considered most convenient for the members.

INVESTMENT OF FUNDS.

28.—As much of the funds of the Institute as may not be wanted for immediate use, or to meet the usual accruing liabilities, shall, with the consent of the Council, or of a majority of the members of the Institute present at a General Meeting, be invested by the Trustees in such of the following ways as the Council or General Meeting shall direct, namely, in the Post Office Savings Bank, in the Public Funds, or with the Commissioners for the Reduction of the National Debt, npon Government or real securities in Great Britain, or upon the security of any County, Borough, or other rates authorised to be levied or mortgaged by Act of Parliament.

ANNUAL AND OTHER RETURNS.

29.—It shall be the duty of the Committee of Management to keep a copy of the last annual balance sheet of the Society for the time being, together with the Report of the Auditors, if any, always hung up in a conspicuous place at the Registered Office of the Society.—Friendly Societies Act, 1875, s. 14, (1 *i*.)

30.—The books and accounts of the Society shall be open to the inspection of any member or person having an interest in the funds of the Society at all reasonable times, at the registered office of the Society, or at any place where the same are kept, and it shall be the duty of the Secretary to produce them for inspection accordingly.

31.—Every year before the 1st June, the Committee of Management shall cause the Secretary to send to the Registrar the annual return, in the form prescribed by the Chief Registrar of Friendly Societies, required by the Friendly Societies Act, 1875, of the receipts and expenditure, funds and effects of the Society, and of the number of members of the same, up to the 31st December then last inclusively, as audited and laid

before a General Meeting, showing separately the expenditure in respect of the several objects of the Society, together with a copy of the Auditors' Report, if any.

32.—Such return shall state whether the audit has been conducted by a public auditor appointed under the Friendly Societies Act, 1875, and by whom, and if such audit has been conducted by any persons other than a public auditor, shall state the name, address, and calling or profession of each of such persons, and the manner in which, and the authority under which, they were respectively appointed.—Friendly Societies Act, 1875, s. 14 (1 *d.*).

33.—It shall be the duty of the Committee of Management to provide the Secretary with a sufficient number of copies of the annual return, or of some balance sheet, or other document duly audited, containing the same particulars as in the annual return as to the receipts and expenditure, funds and effects of the Society, for supplying gratuitously every member or person interested in the funds of the Society, on his application, with a copy of the last annual return of the Society, or of such balance sheet or other document as aforesaid, for the time being, and it shall be the duty of the Secretary to supply such gratuitous copies on application accordingly.—Friendly Societies Act, 1875, s. 14 (1 *h.*).

DISSOLUTION.

34.—The Society may at any time be dissolved by the consent of three-fourths of the members, including honorary members, if any, testified by their signatures to some instrument of dissolution in the form provided by the Treasury Regulations in that behalf.

DISPUTES.

35.—If any dispute shall arise between a member, or person claiming through a member, or under the Rules of the Society, and the Society, or any officer thereof, it shall be referred to justices pursuant to the Friendly Societies Act, 1875, s. 22 (*c.*).

APPENDIX.

FORM A.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

Mr.

of being desirous of becoming a member of the Institute, we, the undersigned, believing him to be fully eligible, hereby recommend him for election.

His qualifications are

Witness our hands this day of 19

} Names of two members.

This application shall be considered by a Committee, consisting of the President and vice-President (for the time being), and the Secretary, and if they approve of the application, it shall be submitted to a General Meeting for refusal or adoption.

FORM B.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

To

SIR,

I beg to inform you that on the you were elected a member of The Staffordshire Iron and Steel Institute, but in conformity with the Rules, your election cannot be confirmed until the accompanying form be returned with your signature, together with your Entrance Fee and first Annual Subscription. (Amount, £ s. d)

If this amount be not received in one month from this date, your election will become void.

I am, Sir,

Yours truly,

Secretary.

day of 19

FORM C.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

I, the undersigned, being elected a member of the Staffordshire Iron and Steel Institute, do hereby agree that I will be governed by the rules of the Institute, and that I will advance its interests as far as may be in my power. Provided that if I signify in writing to the Secretary that I am desirous of withdrawing my name therefrom, I shall (after paying all arrears which may be due by me at that period) be free from this obligation.

Witness my hand this day ot 19

Member's Signature.

FORM D.

THE STAFFORDSHIRE IRON AND STEEL INSTITUTE.

Dear Sir,

I am directed by the Council to inform you that your subscrip'ion to the Institute, amounting to
is still in arrear, and that if the same be not paid to me on or before the
day of your name will be
removed from the lists of the Institute.

Yours faithfully,

Secretary.

OFFICERS FOR SESSION 1903-1904.

President:

WALTER SOMERS, J.P.

Vice-President:

WILLIAM BROOKS.

Trustees:

ALFRED COOKSON, MOSES MILLARD, WILLIAM B. RUBERY.

Treasurer:

JAMES PIPER.

Council:

THOMAS ASHTON
JOHN BATE
JOSEPH BROWN
ALFRED COOKSON
JAMES DONECHAY
DAVID EVANS
H. LE NEVE FOSTER
W. J. FOSTER
J. W. HALL
WALTER JONES
R. LYTHGOE
MOSES MILLARD
FRANK EAST NURSE
HENRY PARRY
HARRY SILVESTER
WILLIAM SOMERS
LEYSHON D. THOMAS
H. B. TOY
ALEXANDER E. TUCKER
THOMAS TURNER
WILLIAM YEOMANS

Secretary:

WILLIAM H. CARDER, Tividale Road, Burnt Tree, Tipton.

PAST PRESIDENTS.

-WILLIAM LESTER
-JOHN BROWN
-JOHN WRIGHT
-SAMUEL NEWTON
-WILLIAM EDWARDS
-JOHN FINNEMORE
-AMBROSE BEARDS.
-JOHN FIELDHOUSE
-WILLIAM MOLINEAUX
-HENRY HUGHES
-WILLIAM FARNWORTH
-JOHN WRIGHT
-WALTER HEELEY
-JAMES RIGBY
-EDWARD HARRIS
-JOSEPH MORRIS
-RICHARD EDWARDS
-MOSES MILLARD
-WILLIAM JNO. HUDSON

1885.—RICHARD SMITH CASSON
1886.—HENRY FISHER
1887.—GEORGE B. WRIGHT
1888.—HENRY PARRY
1889.—ALEXR. E. TUCKER
1890.—HERBERT PILKINGTON
1891.—HERBERT PILKINGTON
1892.—THOMAS TURNER
1893.—JAMES ROBERTS
1894.—THOMAS ASHTON
1895.—WILLIAM B. RUBERY
1896.—WILLIAM YEOMANS
1897.—JNO. W. HALL
1898.—H. LE NEVE FOSTER
1899.—HARRY SILVESTER
1900.—LEYSHON D. THOMAS
1901.—WALTER SOMERS
1902.—WALTER SOMERS

LIST OF MEMBERS.

(CORRECTED TO 29TH SEPTEMBER, 1903).

HONORARY MEMBERS.

Adams, George, and Sons, Limited,
Mars Ironworks, Wolverhampton.

Akrill, C., and Co., Limited,
Gold's Green Foundry, West Bromwich.

Baldwins, Limited,
Wilden, near Stourport.

Bantock, Thos., and Co.,
Wolverhampton.

Bayliss, Jones, and Bayliss, Limited,
Victoria Works, Wolverhampton.

Bohler Brothers and Co.,
Pond Hill, Sheffield.

Bradley, T. and I., and Sons,
Darlaston Green Furnaces, Darlaston.

Bromford Iron Co., Limited,
West Bromwich.

Bunch, B., and Sons,
Staffordshire Ironworks, Walsall.

Chatwin, Thomas,
Market Foundry, Tipton.

Cochrane and Co.,
Woodside Ironworks, Dudley.

Dudley, Earl of,
Priory Offices, Dudley.

Fellows, John,
Compton Grange, Cradley Heath, Staffs.

ırist, P. C., F.R.S. (Life),

Frognal Bank, Finchley Road, Hampstead, London, N. W.

ebrook, M. and W.,

Netherton Ironworks, near Dudley.

t, Josiah, and Sons,

Victoria Foundry, West Bromwich.

is Brothers,

Brierley-Hill.

ison, G. King,

Lye Fire-clay and Brick Works, Stourbridge.

man, A., Limited,

Spring Vale Furnaces, near Wolverhampton.

;ley, N., and Sons, Limited,

Netherton Ironworks, Dudley.

hinson, W.,

7, Park Road, West, Wolverhampton.

s, Walter,

Holly Mount, Red Hill, Stourbridge.

', E. C. and J., Limited,

Prince's Chambers, Corporation-street, Birmingham.

, Henry,

19, Marsh Side, Workington.

wles, J.,

Wolseley House, Wednesbury.

, Maurice,

Parkbridge Ironworks, Ashton-under-Lyne

shall Co., Limited,

Priors Lee Hall, near Shifnal.

d, F. H., and Co , Limited,

James Bridge Steel Works, near Wednesbury.

d and Lloyd, Limited,

Coombs Wood Tube Works, Halesowen, Birmingham

Lones, Vernon, and Holden, Limited,
Smethwick, near Birmingham.

McBean, Alexander, J.P.,
Lichfield-street, Wolverhampton.

Oldbury, I.,
Portland House, Wednesbury.

Parkes, E., and Co.,
Atlas Ironworks, West Bromwich.

Parkes, H. P., and Co., Limited,
Tipton Green Works, Tipton.

Patent Shaft and Axletree Co., Limited,
Wednesbury.

Pearson, J. H.,
Netherton Furnaces, near Dudley.

Perry, James,
69, Finch Road, Handsworth, Birmingham.

Perry, T., and Son, Limited,
Highfields Works, Bilston.

Reay, John G., J.P.,
Rockingham Hall, Hagley, near Stourbridge.

Roberts and Cooper,
Brierley-Hill.

Roberts, J. and S., Limited,
West Bromwich.

Russell, Jno., and Co., Limited,
Cyclops Ironworks, Walsall.

Shropshire Iron Co., Limited,
Hadley, near Wellington, Salop.

Siemens, F.,
10, Queen Anne's Gate, Westminster, S. W.

Simpson, F. F.,
Park Lane Ironworks, Oldbury.

Somers, Walter, J.P.,
Belle Vue, Halesowen, Birmingham.

Spencer, John, Limited,
Globe Tube Works, Wednesbury.

Summers, John, and Sons, Limited,
Globe Ironworks, Stalybridge.

Tangyes, Limited,
Cornwall Works, Birmingham.

Taylor and Farley,
Summit Foundry, West Bromwich.

Walker, J. G.,
7, Trindle Road, Dudley.

Webb, H. A.,
Church-street Chambers, Stourbridge.

Westley, W.,
Shaw Road, Dudley.

Wilkinson, T. A.,
Minerva Ironworks, Wolverhampton.

ORDINARY MEMBERS.

Allen, Caleb A. V.,
Philip-street, Coseley, near Bilston.

Allen, Job,
49, Grange Road, West Bromwich.

Ashton, T.,
"Branksome," Netherton, near Dudley.

Astbury, J.,
Smethwick Foundry, Smethwick, near Birmingham.

Aston, G. B.,
Adelaide Villa, Dudley Road, Wolverhampton.

Baker, Alexr. J.,
Grassington, Green-street, Smethwick.

Baker, Wm. T.,
193, Wednesbury Road, Walsall.

Banks, A. R.,
11, High-street, West Bromwich.

Barklam, Geo ,
Braemar, Dudley Port, Tipton.

Bate, Jno ,
Bamford House, Haden Hill, Old Hill, Staffs.

Belcher, Joseph,
67, Beeches Road, West Bromwich.

Betts, Thomas,
Jervoise-street, West Bromwich.

Blake, Harry B.,
7, Lea Road, Wolverhampton.

Bloomer, Clifford E.,
Shenstonville, Halesowen, Birmingham.

Bloor, W.,
Portfield, Dudley Port, Tipton.

Booth, Horatio,
Rose Mount, John-street, Wordsley, near Stourbridge.

Brooks, W ,
17, Wellington Road, Dudley.

Broughton, W. K.,
Cooper's Hill House, Beeches Road, West Bromwich.

Brown, Joseph,
Sedgley, near Dudley.

Brown, S. J.,
Gold's Hill Post Office, West Bromwich.

Bryce, D.,
Pensnett, Dudley.

Buchanan, Robert,
35, Thornhill Road, Handsworth, near Birmingham.

Burford, H ,
18, Duncombe-street, Wollaston, Stourbridge.

Burt, Jabez.,
40, Dudley Road, West Bromwich.

rt, Joseph,
43, Grange Road, West Bromwich.

rton, Wingfield,
Albert House, Bilston.

rder, W. H.,
Tividale Road, Burnt Tree, Tipton.

lley, J.,
Hillingdon, Dover-street, Bilston.

okson, A.,
Coalbournbrook, Stourbridge.

nks, W. H.,
132, Bridge-street, Wednesbury.

rby, Jno. W.,
39, Parliament-street, Bury, Lancashire.

vies. J. C.,
Wood Green, Wednesbury.

vis, Charles H.,
25, Broad-street, New York City, U.S.A.,

vis, J. Henry G.,
Velindre, Wood Green, Wednesbury.

vitt, Michael,
Netherton Furnaces, Dudley.

aechay, James,
Tipton Green House, Tipton.

'sett, William,
Brookdale, Stourport.

dley, B. J.,
Highfield Lane, Halesowen.

lley, T H.,
45, Level-street, Brierley-Hill.

vards, R ,
The Laurels, 16, Mellish Road, Walsall.

s, John,
Blenheim House, George-street, Reading.

Evans, D.,
Plant-street, Old Hill, near Dudley.

Evans, Frederick Edward,
148, Toll End Road, Tipton.

Evers, H. Lancelot,
White Hall, Stourbridge.

Farnworth, E.,
Broadlands, Goldthorn Hill, Wolverhampton.

Farrington, R. H.,
Station Road, Woodhouse, near Sheffield.

Fieldhouse, J.,
94, St. Paul's Road, West Smethwick.

Fisher, Walter,
Clarence House, Coseley, Bilston

Flavell, Walter J.,
52, Dudley Road, West Bromwich.

Foster, H. Le Neve,
Athenæum Chambers, Temple Row, Birmingham.

Foster, W. J.,
Northfield, Darlaston Road, Walsall.

Gough, William H.,
South Yorkshire Ironworks, Sheffield.

Green, B. J.,
Engineer's House, Water and Sewerage Works, Kidderminster.

Griffin, Edward B.,
Fullwood's End, Coseley, Bilston.

Growcott, J. W.,
Deercroft House, Portway Road, Oldbury, near Birmingham.

Hadley, J. G.,
58, Halesowen-street. Blackheath, Birmingham.

Hall, J. W.,
Athenæum Chambers, 71, Temple Row, Birmingham.

Hammond, H. A.,
Cordley Dudley Road, West Bromwich.

Hammond, Herbert,

Greenfield House, Cradley Heath, Staffordshire.

Hannah, J. C.,

Groveland Road Works, Tipton.

Harley, John,

Waterloo Road, North, Wolverhampton.

Harper, A.,

20, Westbourne-street, Stockton-on-Tees.

Harper, Emmanuel.

Cox's Lane, Old Hill, near Dudley.

Harris, E.,

Amblecote Road, near Brierley-Hill.

Hartland, H.,

Ruiton, near Dudley.

Haskew, Frederick J. T.,

205, Holly Road, Handsworth, Birmingham.

Haslam, Henry B.,

The Mount, Bank Road, Coseley, Bilston.

Hawkins, W. R.,

The Crown Foundry, Dudley Port, Tipton.

Head, George H.,

Grove Cottages, Sedgley Road West, Tipton.

Higgs, Charles H.,

60, Reid-street, Crewe.

Higgs, George,

21, Aukland Road, Smethwick, Birmingham

Hodgkiss, Thomas,

King's Hill Villa, Wednesbury.

Holgate, T. E.,

173, Hollins Grove, Darwen.

Howle, W. H,

16, Bagnall-street, West Bromwich,

Hudson, W. J. (Life),
Stamford Ironstone Mines, Easton, Stamford.

Jacks, T. W. M.,
Hillside, Squire's Walk, Wednesbury.

Jackson, A. W.,
Denby Iron Co., near Derby.

Johnson, Robert,
Chelmer Lodge, Booth-street, Wednesbury.

Jones, Greville T.,
Clarence Ironworks, Port Clarence, Middlesbro'-on-Tees.

Jones, R. E.,
The Poplars, Whitwell, Mansfield.

Keeling, John,
Victoria House, Netherton, near Dudley.

Kendrick, W.,
205, Great Bridge-street, West Bromwich.

Knowles, Thomas R.,
Old Park Terrace, Wednesbury.

Legge, A. H.,
Oldswinford, near Stourbridge.

Lennox, L. Gordon, J.P.,
Newbridge Works, Pontypridd.

Lester, Isaac E.,
57, Westminster Road, Handsworth, Birmingham.

Lewis, John,
Caldwall Foundry, Kidderminster.

Lloyd, J. M.,
Cleveland House, Priestfield, Wolverhampton.

Lowcock, Sidney R., M.Inst.C.E.,
Temple Courts, Birmingham.

Lycett, J. A.,
Castle Hill, Wolverley, near Kidderminster.

Lythgoe, Richard,
Dudley House, Brierley-Hill.

cartney, Frederick N.,
36, Wainwright Grove, Garston, Liverpool.

Bean, Archibald D. G.,
Tyninghame, Tettenhall, Wolverhampton.

:farlane, Walter,
Kelvin, Wednesbury.

Millan, W. G.,
8, Drewstead Road, Streatham, London, S.W.

ıtle, H. G., F.G.S.,
Old Level Ironworks, Brierley-Hill.

chett, James,
10, Dial Lane, Hill Top, West Bromwich.

ty, W. H.,
Langley, near Birmingham.

se, Daniel,
"Lonsdale," Toll End Road, Ocker Hill, Tipton.

sforth, H.,
Inverugie, Valley Road, Chesterfield.

edith, S.,
Tividale Road, Tipton.

klewright, William,
Osborne House, Wood Green Road, Wednesbury.

ard, Frederick J.,
255, Bloxwich Road, Walsall.

ard, M.,
Oakleigh, Humber Road, Wolverhampton.

s, Frederick,
Ebbw Vale Steel, Iron, and Coal Company, Limited, Ebbw Vale, R.S.O., Mon.

ward, Thomas,
The Woodlands, Button Oak, near Bewdley.

neaux, W.,
105, Oxford Street, Bilston.

re, Algernon W.,
Spring Vale House, Ettingshall, Wolverhampton.

Moore, Frank,
Lapal Lodge, Quinton, Birmingham.

Moore, William,
Spring Vale House, Ettingshall, Wolverhampton.

Morris, William,
40, Talbot-street, Oldbury.

Mountford, Percy,
Hagley Road, Stourbridge.

Muras, Robert,
83, Darlington-street, Wolverhampton.

Nicholls, James,
Round Oak, Brierley-Hill.

Nicholson, E. D.,
Llynclys, near Oswestry.

Northwood, Joshua,
109, Oxford-street, Bilston.

Nurse, Alfred E.,
72, Edward-street, West Bromwich.

Nurse, Frank East,
Eastcroft, Grange Road, West Bromwich.

Oakley, Joseph,
21, Perry-street, Darlaston.

Onions, W. J.,
95, Beeches Road, West Bromwich.

Pagett, W. W.,
Wollaston, Stourbridge.

Parker, Joseph A.,
20, Dudley Road, Tipton.

Parry, H.,
The Level, Brierley-Hill.

Partridge, H. E.,
13, Carter's Green, West Bromwich.

Paterson, John (Life),
Belle Isle Place, Workington.

on, J ,

67, Woodland Road, Handsworth, Birmingham.

ngton, H. (Life), M.Inst., C.E.

Sheepbridge Ironworks, Chesterfield.

r, Harold,

The Hawthorns, Collis-street, Amblecote, Stourbridge.

r, J.,

The Hawthorns, Collis-street, Amblecote, Stourbridge.

, A.,

Mount Pleasant, Bilston.

ı, John E.,

17, Sydney-street, Basford Park, Stoke-on-Trent.

›ould, James,

9, Pensnett Road, Brierley-Hill.

ards, W. H.,

Vulcan Foundry, Darlaston.

ɔins, Jno.,

Sedgley Road, Tipton.

nson, Philip,

Emerald Villa, Holly Lane, Smethwick, Birmingham.

:, T. Lawrence,

Wellington Road, Bilston.

ıd, R.,

105, Moor-street, Brierley-Hill.

ery, W. B.,

Ashwood, 76, Dudley Road, Tipton.

ıworth, David,

Clay Cross Ironworks, near Chesterfield.

t, David,

Inglenook, Penn Fields, Wolverhampton.

en, Ernest Arthur,

346, Dudley Port, Tipton.

Screen, William T.,
Fair View, Horseley Heath, Tipton.

Shedden, Duncan J.,
Dixon's Green, Dudley.

Shenton, Jas. W.,
35, Bromford Lane, West Bromwich.

Silvester, H., B.Sc., F.C.S.,
78, Holyhead Road, Handsworth.

Smith, T. H.,
Princes End Foundry, Tipton.

Smith, W. S.,
Neachells Road, Wednesfield, Wolverhampton.

Somers, William,
Haywood Forge, Halesowen, Birmingham.

Summers, Geo. W.,
Old End House, Coseley, Bilston.

Taplin, Henry,
Furnace Hill, Halesowen, Birmingham.

Thomas, E. F.,
Birchills Ironworks, Walsall.

Thomas, F. G.,
Birchills Ironworks, Walsall.

Thomas, L. D.,
Bromley House, Pensnett, near Dudley.

Thompson, E. S.,
Bradley Boiler Works, Bilston.

Thompson, S. J.,
Ettingshall Boiler Works, Wolverhampton.

Toy, Harry B.,
Maiville, Nicholls-street, West Bromwich.

Treglown, C. H.,
38, Wretham Road, Handsworth, Birmingham.

Tucker, A. E., F.I.C.,
35, Paradise-street, Birmingham.

Turley, T.,
Glenleigh, Woodsetton, near Dudley.

Turner, Professor T., M.Sc., A.R.S.M., F.I.C.,
The University, Birmingham.

Venables, W. H.,
Farringford, Vicarage Road, Smethwick.

Waldron, H. Westwood,
Myrtle Cottage, Pritchard-street, Wednesbury.

Wall, Charles H.,
Redclyffe, Halesowen, Birmingham.

Webster, C. W.,
Haden Hill, Old Hill, Staffordshire.

Westwood, Samuel,
Bank Farm, Graveyard Road, Lower Gornal, near Dudley.

Whitehouse, Ernest J.,
77, Dudley Road, Tipton.

Whitmore, Samuel,
Fairoak Avenue, Newport, Mon.

Whittaker, J. H.,
23, Victoria Terrace, Dudley.

Willcox, Thomas,
314, Stoney Lane, Smethwick, Birmingham.

Williams, A.,
Arnside, Gordon-street, Darlaston.

Williams, G.,
Parkbridge Ironworks, Ashton-under-Lyne.

Winwood, Thomas,
Park Road, Dudley.

Wootton, Thomas,
86, High-street, Blackheath, near Birmingham.

Worton, Fred.,
The Orchard, Round Oak, Brierley-Hill.

Wright, Edward,
Mostyn Villa, Lower Hill-street, Stourbridge.

Yates, Charles R.,
Park Villa, Wood Green, Wednesbury.

Yeomans, C.,
Talbot-street, Brierley-Hill.

Yeomans, W.,
Hawes Hill, Rowley Regis, near Birmingham.

LIBRARY.

The "Proceedings" of the Institute are exchanged for those of the ollowing Institutions, etc.:—

Institution of Mechanical Engineers,
Iron and Steel Institute,
North of England Institute of Mining and Mechanical Engineers,
Royal Scottish Society of Arts,
West of Scotland Iron and Steel Institute,
American Institute of Mining Engineers,
American Society of Mechanical Engineers,
Franklin Institute, Philadelphia;
Smithsonian Institution, Washington, D.C.;
Nova Scotian Institute of Science, Halifax, N.S.;
Royal University Library, Upsala;
"Colliery Guardian,"
"Engineering,"
"Ironmonger," London;
"Iron and Coal Trades Review,"
"Iron and Steel Trades Journal,"
"Science and Art of Mining,"
"Page's Magazine."

They are also presented to the Library of the Patent Office, London; and the Library of the University, Birmingham.

Additions to the Library since issue of Volume for 1901-1902.

No. in Catalogue.	Title.	By whom present
58	Proceedings of the Staffordshire Iron and Steel Institute, 1902-1903. Vol. XVIII. ...	The Institute.
165	Journal of the Iron and Steel Institute, 1902. Vol. II. ...	Do.
166	Journal of the Iron and Steel Institute, 1903. Vol. I. ..	Do.
236	Bulletin of the Geological Institution of the University of Upsala. 1901	The University.
265	Transactions of the American Society of Mechanical Engineers, 1902 ...	The Society.
330	Journal of the West of Scotland Iron and Steel Institute. Vol. IX. ...	The Institute.
331	Do. do. Vol. X. ...	Do.
359	Proceedings of the Nova Scotian Institute of Science, 1900-1901 ...	Do.
413	Journal of the Franklin Institute, July – December, 1902	Do.
415	Proceedings of the Institution of Mechanical Engineers, 1902 ...	Do.
419	Journal of the Franklin Institute, January—June, 1903	Do.

RULES

REGULATING THE USE OF BOOKS BELONGING TO THE

LIBRARY.

1.—Members of the Institute whose subscriptions are fully paid up ill be entitled to the Loan of Books from the Library, subject to the nditions embodied in these Rules.

2.—The Library shall be open on such days and at such hours as the mmittee may appoint, but pending the establishment of a regular brary room, application must be made to the Librarian in writing for e loan of a book.

3.—A member shall not be allowed to have more than one volume at time, unless the work consists of two or more parts. The period of an will, however, in such a case, be the same as for one volume.

4.—Single parts of "Transactions" issued by any Scientific or other nstitution will be considered as one volume, except where a number of uch parts are bound in one cover.

5—The time allowed for the perusal of any volume shall be 28 days, ut when the Institute is in active session, and then only, this rule may, r the convenience of members residing more than two miles from the ibrary, be construed as meaning the time between one monthly meeting nd another.

6.—The Librarian shall, in writing, demand the return of any book ept beyond the time stipulated in Rule 5; the expenses incurred to be aid by the member so retaining the book.

7.—Any member lending a book belonging to this Library to a person utside his own household will be fined One Shilling; and on repetition e Committee shall be empowered to suspend his privileges

8.—If a book be lost, written in, or damaged, the member who last borrowed it shall either pay the value of the same, or replace it by another of the same title, or make such reparation as the Committee may determine. In order to prevent disputes respecting this Rule, borrowers of books are requested to examine the condition of each volume when it is issued by the Librarian, so that any injury may be pointed out.

9.—A member of the Institute who may wish to recommend a work for the Library, shall give to the Librarian, in writing, particulars of its title and price, and the name of the publisher.

10.—Each member who may desire to avail himself of the privileges of the Library, shall be furnished with a copy of these Rules and a Library Card. The card bearing the name of the borrower will be countersigned by the Secretary of the Institute, and unless this card is presented when application is made for a book the Librarian will decline to issue any volume.

11.—Every member who receives a copy of these Rules is considered as binding himself to conform to them.

LIBRARY CATALOGUE.

No.	Work.			
1	Proceedings of the Institution of Mechanical Engineers—General Index 1847 to 1880			
2	Do.	do.	do.	1847-8-9
3	Do.	do.	do.	1850-1
4	Do.	do.	do.	1852
5	Do.	do.	do.	1853
6	Do.	do.	do.	1854
7	Do.	do.	do.	1855
8	Do.	do.	do.	1856
9	Do.	do.	do.	1857
10	Do.	do.	do.	1858
11	Do.	do.	do.	1859
12	Do.	do.	do.	1860
13	Do.	do.	do.	1861
14	Do.	do.	do.	1862
15	Do.	do.	do.	1863
16	Do.	do.	do.	1864
17	Do.	do.	do.	1865
18	Do.	do.	do.	1866
19	Do.	do.	do.	1867

Ↄ. WORK.

Proceedings of the Institution of Mechanical Engineers,			1868
Do.	do.	do.	1869
Do.	do.	do.	1870
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Do.	do.	do.	1873
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Do.	do.	do.	1881
Do.	do.	do.	1882
Do.	do.	do.	1883
Do.	do.	do.	1884
Do.	do.	General Index,	1874 to 1884
Do.	do.	do.	1885
Do.	do.	do.	1886
Do.	do.	do.	1887
Do.	do.	do.	1888
Do.	do.	do.	1889
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Do.	do.	do.	1895
Do.	do.	do.	1896
Do.	do.	do.	1897
Do.	do.	do.	1898
Do.	do.	do.	1899
Do.	do.	do.	1900
Do.	do.	do.	1901
Do.	do.	do.	1902

Blast Furnace Practice, Charles Cochrane.
Boiler Explosions, Vol. 1 (1862 to 1879), E. B. Marten.
Do. do. Vol. 2 (1880 to 1887), do.
Lime as a Flux in Blast Furnace Practice, and other papers, C. Cochrane
Momentary Depression of the Elastic Limit of Steel, at Two Critical Temperatures, Henry M. Howe, A.M., S.B.
Address on Technical Education, do.
Manganese Steel, do.
Notes on the Bessemer Process, do.
Preliminary report on the Thermal properties of Slags, do.
Copper Smelting, do.
Phillips' Metallurgy.
Papers on Puddling, &c., Kirk and Howson.
Papers on Iron, &c., Thomas Turner.
The Steam Engine, E. A. Cowper.
Gaseous Fuel, B. H. Thwaite.
Luminous and Non-Luminous Combustion, B. H. Thwaite.
The London Smoke Plague—a proposed Remedy, B. H. Thwaite.
American Meeting of Iron and Steel Institute, 1890.
The Influence of Silicon in Cast-iron, W J. Keep.
Phosphorus in Cast-iron, W. J. Keep.
The Influence of Manganese in Cast-iron, W. J. Keep.
Proceedings South Staffordshire Institute of Iron and Steel Works' Managers Vol. 1

No.	Work.
72	Proceedings South Staffordshire Institute of Iron and Steel Works' Managers (1886—1887), Vol. 2
73	Do. do. do. (1887—1888), Vol. 3
74	Do. do. do. (1888—1889), Vol. 4
75	Do. do. do. (1889—1890), Vol. 5
76	Do. do. do. (1890—1891), Vol. 6
77	Do. do. do. (1891—1892), Vol. 7
78	Do. do. do. (1892—1893), Vol. 8
79	Do. do. do. (1893—1894), Vol. 9
80	Do. do. do. (1894—1895), Vol. 10
81	Do. do. do. (1895—1896), Vol. 11
82	Do. do. do. (1896—1897), Vol. 12
83	Do. do. do. (1897—1898), Vol. 13
84	Do. do. do. (1898—1899), Vol. 14
85	The Staffordshire Iron and Steel Institute (1899—1900), Vol. 15
86	Do. do. do. (1900—1901), Vol. 16
87	Do. do. do. (1901—1902), Vol. 17
88	Do. do. do. (1902—1903), Vol. 18
101	Papers read before the Iron and Steel Institute, from 1869 to 1881.
102	Journal of the Iron and Steel Institute ... ... 1873 No. 1
103	Do. do. do. ... ... 1873 No. 2
104	Do. do. do. ... ... 1874 No. 1
105	Do. do. do. ... ... 1874 No. 2
106	Do. do. do. ... ... 1875 No. 1
107	Do. do. do. ... ... 1875 No. 2
108	Do. do. do. ... ... 1876 No. 1
109	Do. do. do. ... ... 1876 No. 2
110	Do. do. do. ... ... 1877 No. 1
111	Do. do. do. ... ... 1877 No. 2
112	Do. do. do. ... ... 1877 No. 3
113	Do. do. do. ... ... 1878 No. 1
114	Do. do. do. ... ... 1878 No. 2
115	Do. do. do. ... ... 1879 No. 1
116	Do. do. do. ... ... 1879 No. 2
117	Do. do. do. ... ... 1880 No. 1
118	Do. do. do. ... ... 1880 No. 2
119	Do. do. do. ... ... 1881 No. 1
120	Do. do. do. ... ... 1881 No. 2
121	Do. do. do. ... ... 1882 No. 1
122	Do. do. do. ... ... 1882 No. 2
123	Do. do. do. ... ... 1883 No. 1
124	Do. do. do. ... ... 1883 No. 2
125	Do. do. do. ... ... 1884 No. 1
126	Do. do. do. ... ... 1884 No. 2
127	Do. do. do. ... ... 1885 No. 1
128	Do. do. do. ... ... 1885 No. 2
129	Do. do. do. ... ... 1886 No. 1
130	Do. do. do. ... ... 1886 No. 2
131	Do. do. do. ... ... 1887 No. 1
132	Do. do. do. ... ... 1887 No. 2
133	Do. do. do. ... ... 1888 No. 1
134	Do. do. do. ... ... 1888 No. 2
135	Do. do. do. ... ... 1889 No. 1
136	Do. do. do. ... ... 1889 No. 2
137	Do. do. do. ... ... 1890 No. 1
138	Do. do. do. ... ... 1890 No. 2
139	Do. do. do. ... ... 1891 No. 1
140	Do. do. do. ... ... 1891 No. 2
141	Do. do. do. ... ... 1891, American
142	Do. do. do. ... ... 1892 No. 1

No.	Work.			
	Journal of the Iron and Steel Institute	... ...	1892	No. 2
	Do. do. do.	... ..	1893	No. 1
	Do. do. do.	... ..	1893	No. 2
	Do. do. do.	... ..	1894	No. 1
	Do. do. do.	... ...	1894	No. 2
	Do. do. do.	... ...	1895	No. 1
	Do. do. do.	... ...	1895	No. 2
	Do. do. do.	... ...	1896	No. 1
	Do. do. do.	... ...	1896	No. 2
	Do. do. do.	.. ...	1897	No. 1
	Do. do. do.	... ...	1897	No. 2
	Do. do. do.	... ...	Index. 1869-1896	
	Do. do. do.	... ...	1898	Vol. 1
	Do. do. do.	.. ...	1898	Vol. 2
	Do. do. do.	... ..	1899	Vol. 1
	Do. do. do.	... ...	1899	Vol. 2
	Do. do. do.	... ...	1900	Vol. 1
	Do. do. do.	... ...	1900	Vol. 2
	Do. do. do.	... ..	1901	Vol. 1
	Do. do. do.	... ...	1901	Vol. 2
	Do. do. do.	...	General Index, 1890-1900	
	Do. do. do.	... ...	1902	Vol. 1
	Do. do. do.	... ...	1902	Vol. 2
	Do. do. do.	.. ..	1903	Vol. 1
	Annual Report of Smithsonian Institution, U.S.A.	..	1884	
	Do. do.	(National Museum)	1884	
	Do. do.	..	1885	
	Do. do.	(National Museum)	1885	
	Do. do.		1886	
	Do. do.	(National Museum)	1886	
	Do. do.		1887	
	Do. do.	(National Museum)	1887	
	Do. do.		1888	
	Do. do.	(National Museum)	1888	
	Do. do.		1889	
	Do. do.	(National Museum)	1889	
	Do. do.		1890	
	Do. do.	(National Museum)	1890	
	Do. do.	...	1891	
	Do. do.	...	1892	
	Do. do.	...	1893	
	Do. do.	(National Museum)	1891	
	Do. do.	(do.)	1892	
	Do. do.	(do.)	1893	
	Do. do.	(do.)	1894	
	Do. do.	...	1894	
	Do. do.	.	1895	
	Earth Crust Movements and their Causes, Joseph Le Conte.			
	Report of the Naval Court of Inquiry upon the destruction of the U.S. Battleship *Maine*, in Havana Harbour, February 15th, 1898.			
	The Rarer Metals and their Alloys, Austen.			
	Bulletin of the Geological Institution of the University of Upsala	... ...	1892	
	Do. do. do.		1893	
	Do. do. do.		1894	
	Do. do. do.		1895	
	Do. do. do.		1896	
	Do. do. do.		1897	
	Do. do. do.		1898	
	Do, do. do.		1899	

No.	Work.			
72	Proceedings South Staffordshire Institute of Iron and Steel V Managers			(1886–1887),
73	Do.	do.	do.	(1887–1888),
74	Do.	do.	do.	(1888–1889),
75	Do.	do.	do.	(1889–1890),
76	Do.	do.	do.	(1890–1891),
77	Do.	do.	do.	(1891–1892),
78	Do.	do.	do.	(1892–1893),
79	Do.	do.	do.	(1893–1894),
80	Do.	do.	do.	(1894–1895),
81	Do.	do.	do.	(1895–1896),
82	Do.	do.	do.	(1896–1897),
83	Do.	do.	do.	(1897–1898),
84	Do.	do.	do.	(1898–1899),
85	The Staffordshire Iron and Steel Institute			(1899–1900),
86	Do.	do.	do.	(1900–1901),
87	Do.	do.	do.	(1901–1902),
88	Do.	do.	do.	(1902–1903),
101	Papers read before the Iron and Steel Institute, from 1869 to 1881.			
102	Journal of the Iron and Steel Institute		... ...	1873
103	Do.	do.	do.	1873
104	Do.	do.	do.	1874
105	Do.	do.	do.	1874
106	Do.	do.	do.	1875
107	Do.	do.	do.	1875
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114	Do.	do.	do.	1878
115	Do.	do.	do. . ..	1879
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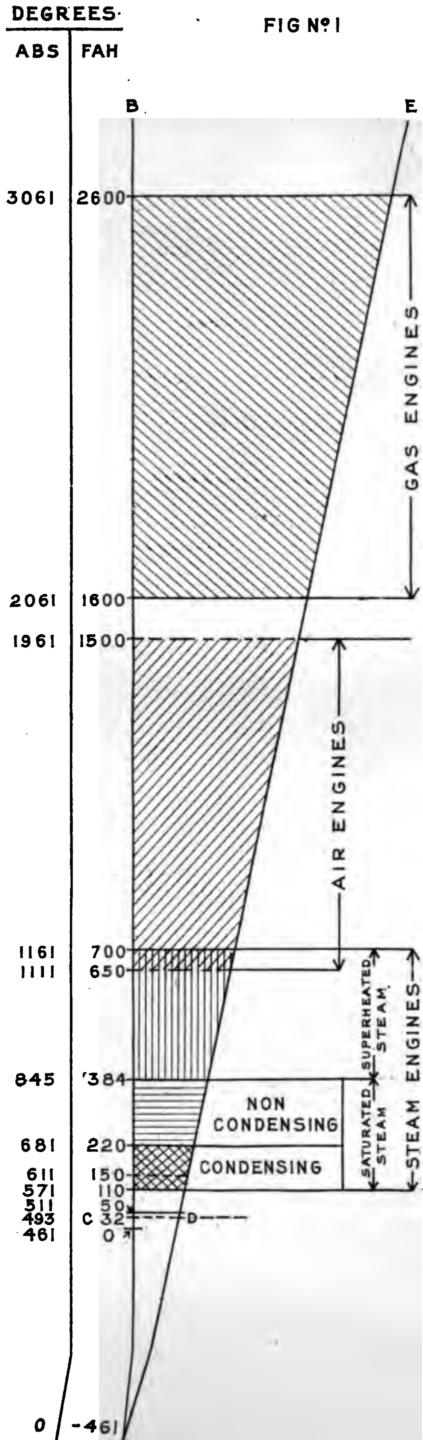
138	Do.	do.	do.	1890
139	Do.	do.	do.	1891
140	Do.	do.	do.	1891
141	Do.	do.	do.	1891, An
142	Do.	do.	do.	1892

No.	Work.			
235	Bulletin of the Geological Institution of the University of Upsala	...	...	1900
236	Do.	do.	do.	1901
251	Transactions of the American Society of Mechanical Engineers	...	...	1888
252	Do.	do.	do.	1889
253	Do.	do.	do.	1890
254	Do.	do.	do.	1891
255	Do.	do.	do.	1892
256	Do.	do.	do.	1893
257	Do.	do,	do.	1894
258	Do.	do.	do.	1895
259	Do.	do.	do.	1896
260	Do.	do.	do.	1897
261	Do.	do.	do.	1898
262	Do.	do.	do	1899
263	Do.	do	do.	1900
264	Do.	do.	do	1901
265	Do.	do.	do.	1902
275	Papers read before the American Institute of Mining Engineers	...	...	1890
276	Do.	do.	do.	1891
277	Do.	do.	do.	1892
278	Do.	do.	do.	1893
279	Do.	do.	do.	1894
280	Do.	do.	do.	1895
281	Do.	do.	do.	1896
282	Do.	do.	do.	1897
283	Do.	do.	do.	1898
301	Transactions of the North of England Institute of Mining and Mechanical Engineers		...	Vol. 38
302	Do.	do.	do.	Vol. 39
303	Do.	do.	do.	Vol. 40
304	Do.	(Report of French Commission on Fire Damp)		
305	Do.	do.	do.	Vol. 41
306	Do.	do.	do.	Vol. 42
307	Do.	do.	do.	Vol. 43
308	Do.	do.	(Boring and Sinking, S.T.)	
309	Do.	do.	(Part 1 of Flameless Explosive Report.)	
310	Do.	do.	(Part 2 of do.	Westfalit, etc.)
311	Do.	do.	(Part 3 of do.	)
312	Do.	do.	do.	Vol. 44
313	Do.	do.	do.	Vol. 45
314	Do.	do.	do.	Vol. 46
315	Do.	do.	do.	Vol. 47
316	Do.	(Strata of Northumberland and Durham, U—Z.)		
317	Do.	do.	do.	Vol. 48
318	Do.	do.	do.	Vol. 49
319	Do.	do.	do.	Vol. 50
320	Do.	do.	do.	Vol. 51
417	Do.	do.	do.	Vol. 52
418	Do.	do.	do.	Vol. 53
321	Journal of the West of Scotland Iron and Steel Institute,		Vol.	I. 1892–9
322	Do.	do.	do. Vol.	II. 1894–9
323	Do.	do.	do. Vol.	III. 1895–9
324	Do.	do.	do. Vol.	IV. 1896–9
325	Do.	do.	do. Vol.	V. 1897–9
326	Do.	do,	do. Vol.	VI. 1898–9

No.	Work.
327	Journal of the West of Scotland Iron and Steel Institute,
	Do. do. do. Vol. VII. 1899–00
328	Do. do. do. Vol. VIII. 1900–01
329	Do. do. do. Vol. IX. 1901–02
330	Do. do. do. Vol. X. 1902–03
351	Proceedings of The Nova Scotian Institute of Science ... 1892–93
352	Do. do. do. ... 1893–94
353	Do. do. do. ... 1894–95
354	Do. do. do. ... 1895–96
355	Do. do. do. ... 1896–97
356	Do. do. do. ... 1897–98
357	Do. do. do. ... 1898–99
358	Do. do. do. ... 1899–00
359	Do. do. do. .. 1900–01
361	Transactions of The Royal Scottish Society of Arts, Vol. VIII.
362	Do. do. do. Vol. IX.
363	Do. do. do. Vol. X.
364	Do. do. do. Vol. XI.
365	Do. do. do. Vol. XII.
366	Do. do. do. Vol. XIII.
367	Do. do. do. Vol. XIV.
368	Do. do. do. Vol. XV.
381	Metallurgy of Iron, T. Turner.
382	Engineer's and Contractor's Book of Prices, 1895–1896, Spon.
383	Patent Law of all Countries, Thompson.
384	Digest of Physical Tests and Laboratory Practice, No. 1.
385	Do. do. do. No. 2.
386	An Improved Method of Utilising Canals for Traffic, W. B. Cook and F. Willoughby.
387	Digest of Physical Tests and Laboratory Practice, Vol. 2, No. 1.
391	Journal of the Franklin Institute, U.S.A., May, 1895.
392	Do. do. do. June, 1895.
393	Do. do. do. July—December, 1895.
394	Do. do. do. January—June, 1896.
395	Do. do. do. July—December, 1896.
396	Do. do. do. January—June, 1897.
397	Do. do. do. July—December, 1897.
398	Do. do. do. January—June, 1898.
399	Do. do. do. July—December, 1898.
400	Do. do. do. January—June, 1899.
401	Do. do. do. July—December, 1899.
403	Report of Chief Engineer of Manchester Steam Users' Association, May, 1899.
404	Journal of the Franklin Institute, U.S.A., January—June, 1900.
405	Do. do. do. July—December, 1900.
406	Report of Chief Engineer of Manchester Steam Users' Association, May, 1900.
409	Journal of the Franklin Institute, U.S.A., January—June, 1901.
410	Do. do. do. July—December, 1901.
411	Report of Chief Engineer of Manchester Steam Users' Association, June, 1901.
412	Journal of the Franklin Institute, U.S.A., January—June, 1902.
413	Do. do. do. July—December, 1902.
414	Subject matter Index of Mining, Mechanical, and Metallurgical Literature for 1900.
419	Journal of the Franklin Institute, U.S.A., January—June, 1903.

INDEX

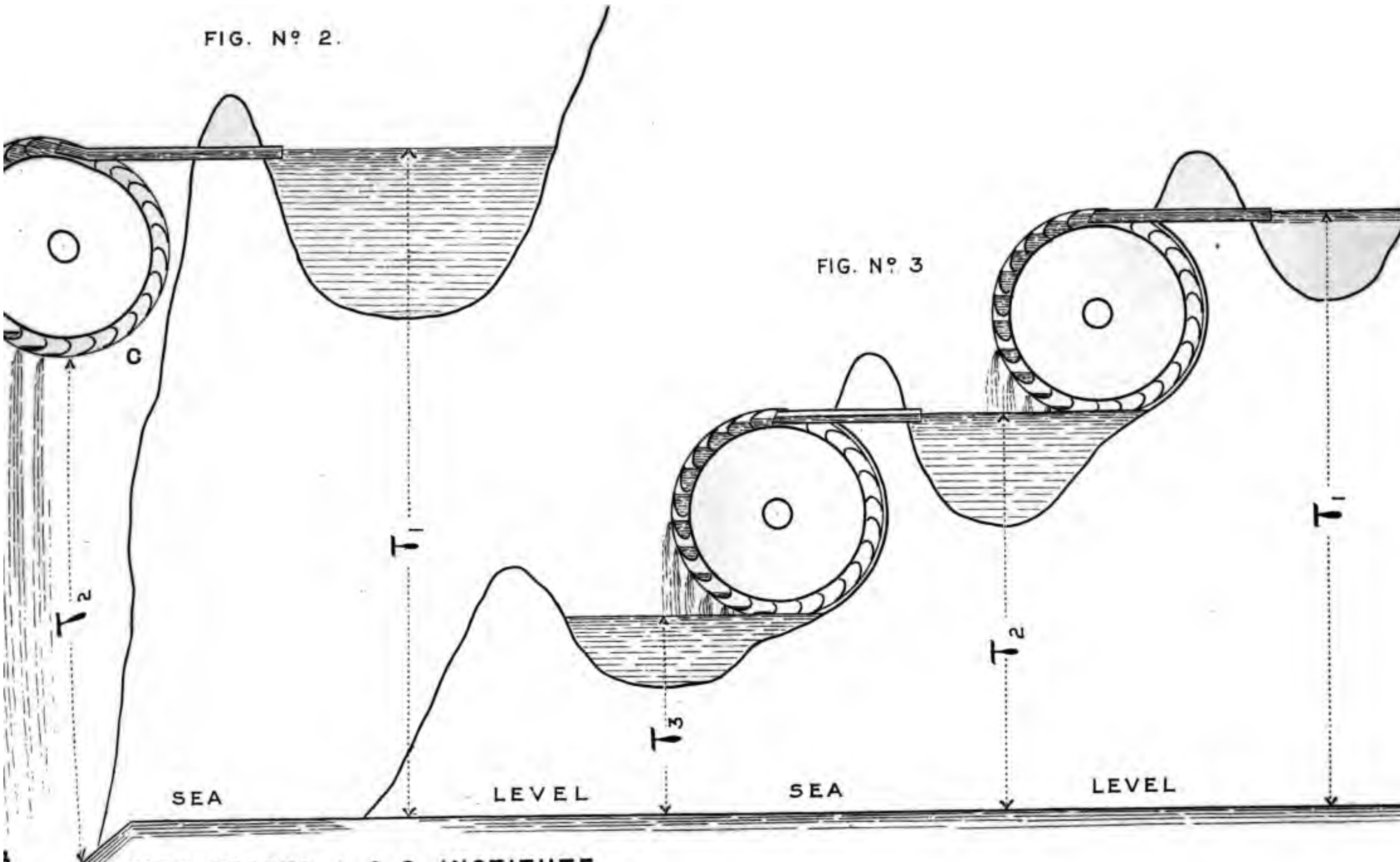
FIG No. 1



DEGREES
ABS
FAH
B
E
3061
2600
2061
1600
1961
1500
1161
700
1111
650
845
384
681
220
611
150
571
110
511
50
493
C 32
D
461
0
0
-461
A
GAS ENGINES
AIR ENGINES
SUPERHEATED STEAM
SATURATED STEAM
STEAM ENGINES
NON CONDENSING
CONDENSING

FIG. Nº 2.

FIG. Nº 3



Mr. Axel Sahlin's Paper on "The Modern Continuous Rolling Mill."

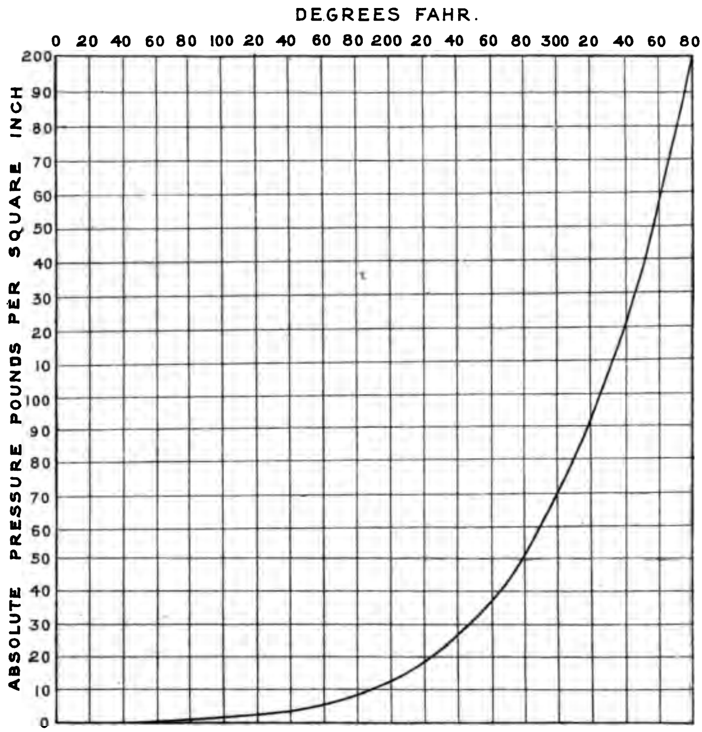
FIG. 3.

Method of handling Billets.

Mr. JNO. W. HALL'S PAPER ON GAS AND OTHER HEAT ENGINES.

FIG. No. 4

PRESSURE & TEMPERATURE OF SATURATED STEAM.



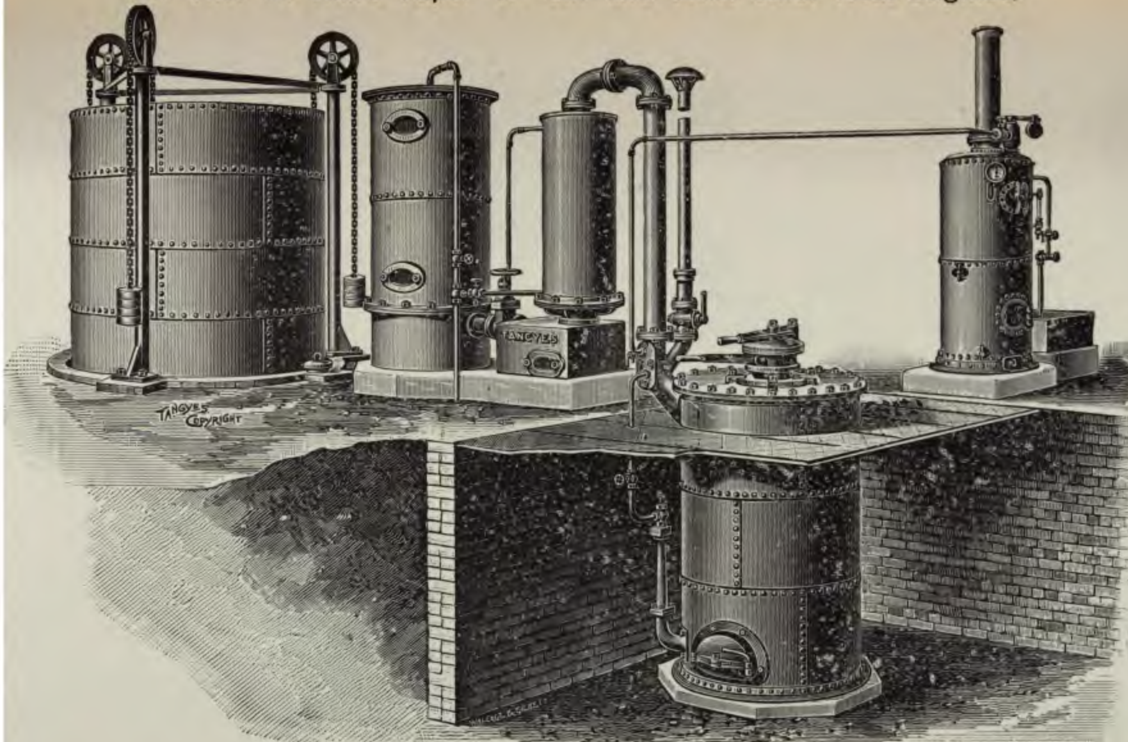


Fig. No. 5.

Mr. Jno. W. Hall's Paper on Gas and some other Heat Engines.

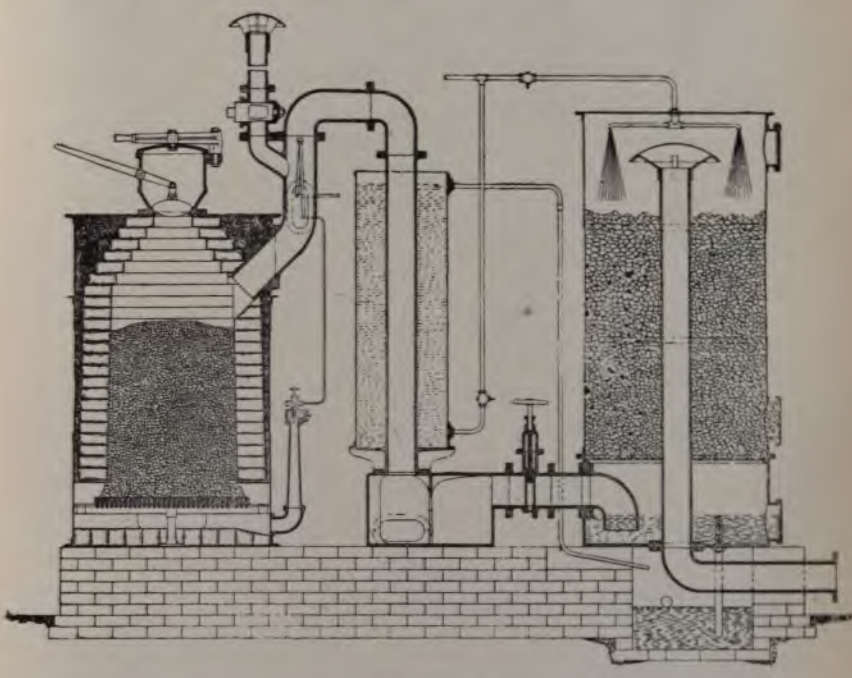


Fig. No. 6.

Mr. Jno. W. Hall's Paper on Gas and some other Heat Engines.

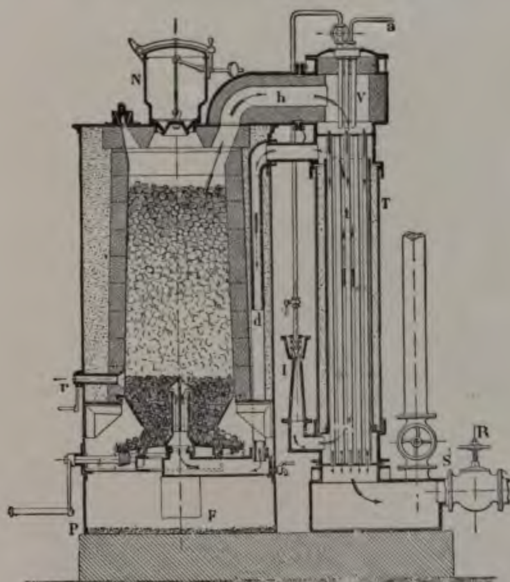
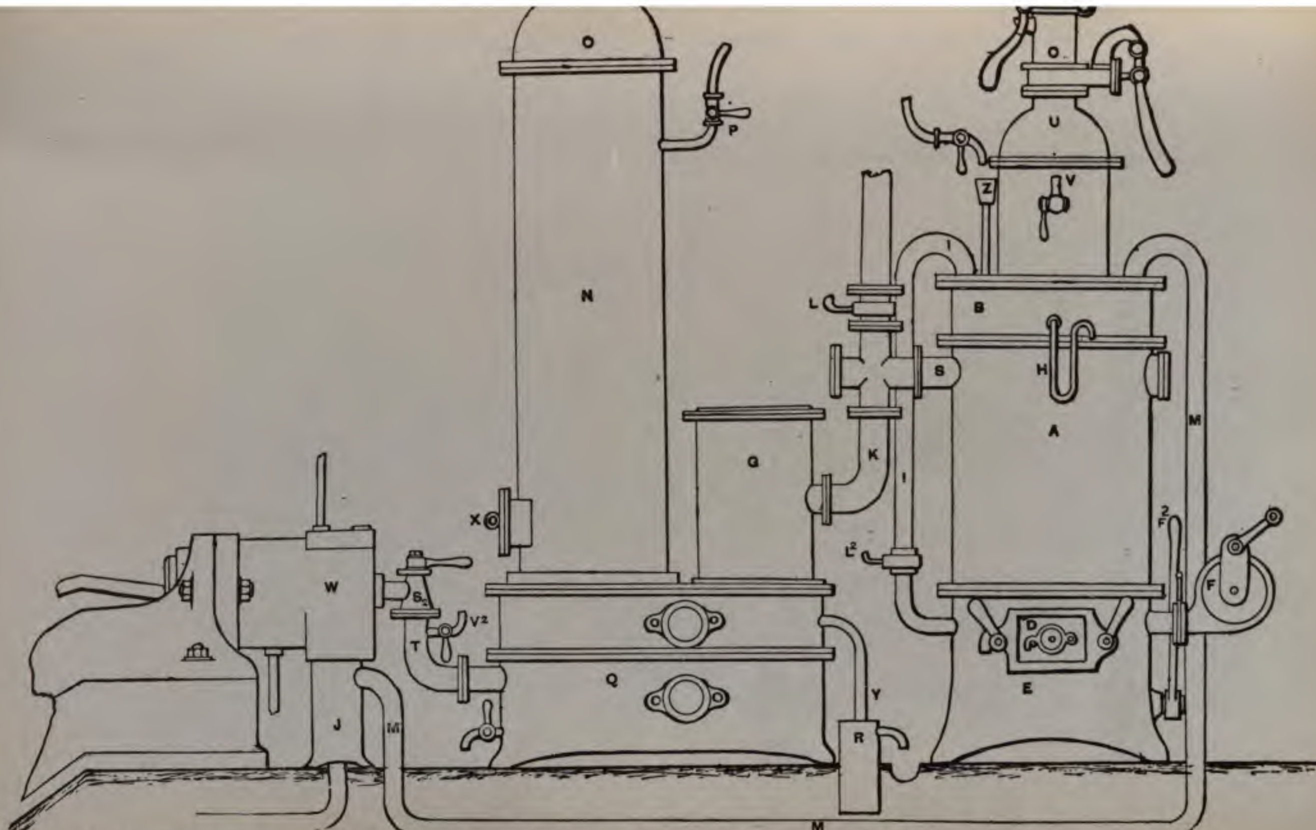


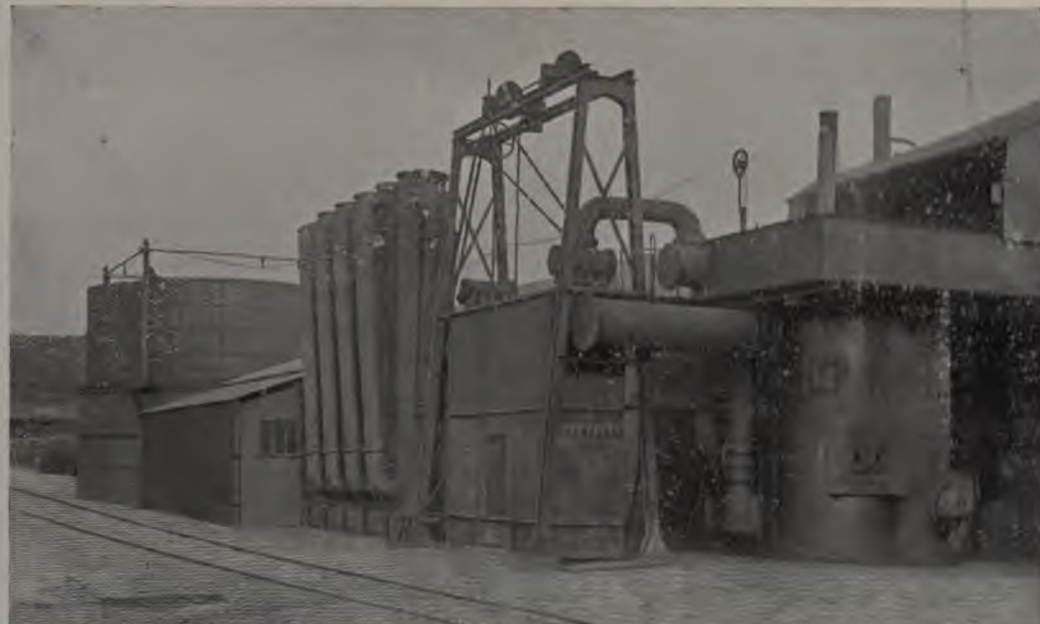
Fig. No. 7.



PROCEEDINGS STAFFS. I. & S. INST.,
SESSION 1902—1903.

Fig. No. 8.

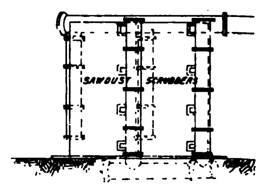
Mr. Jno. W. Hall's Paper on Gas and some other Heat Engines.

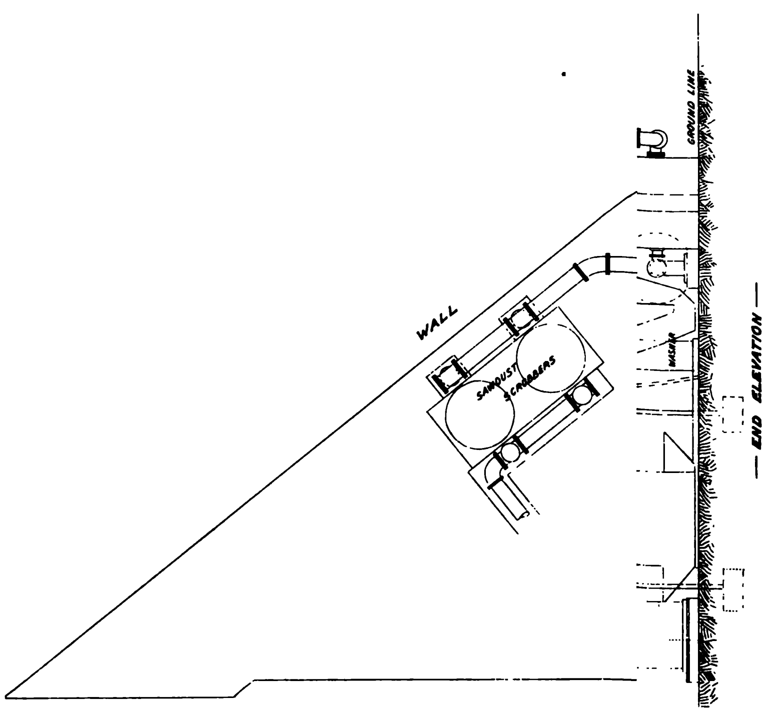


PROCEEDINGS STAFFS I. & S. INST.
SESSION 1902–1903.

Fig. No. 9.

MR. JNO. W. HALL'S PAP





NEW YORK

Jno. W. Hall's Paper on Gas and some other Heat Engines.

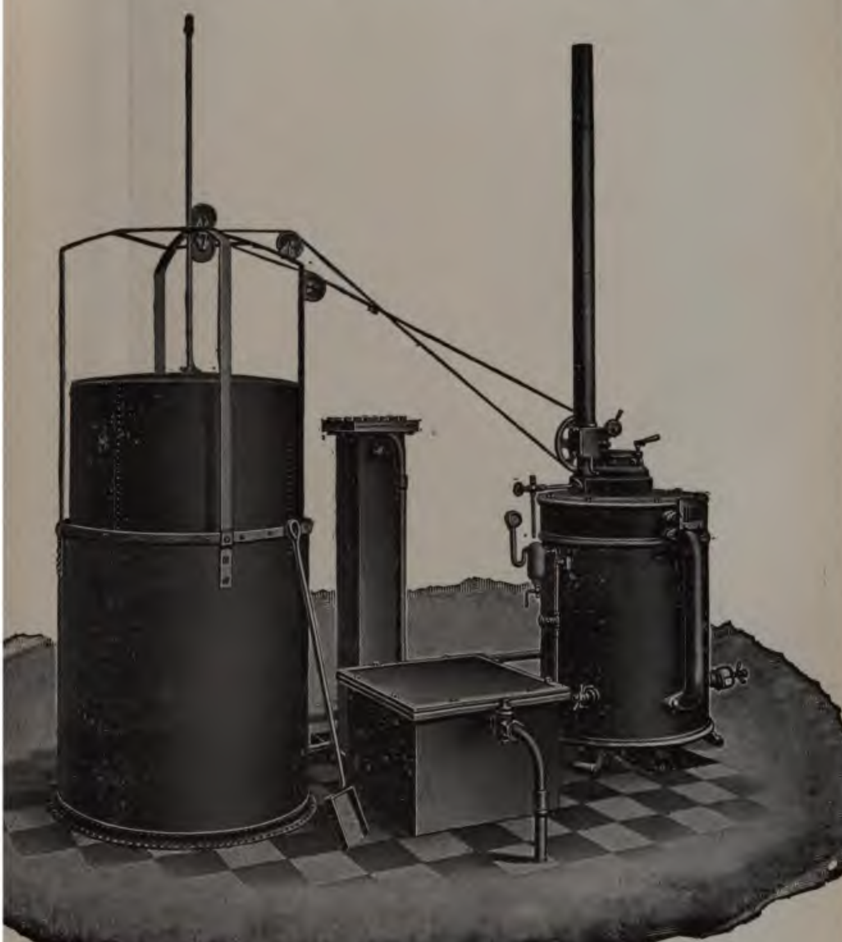
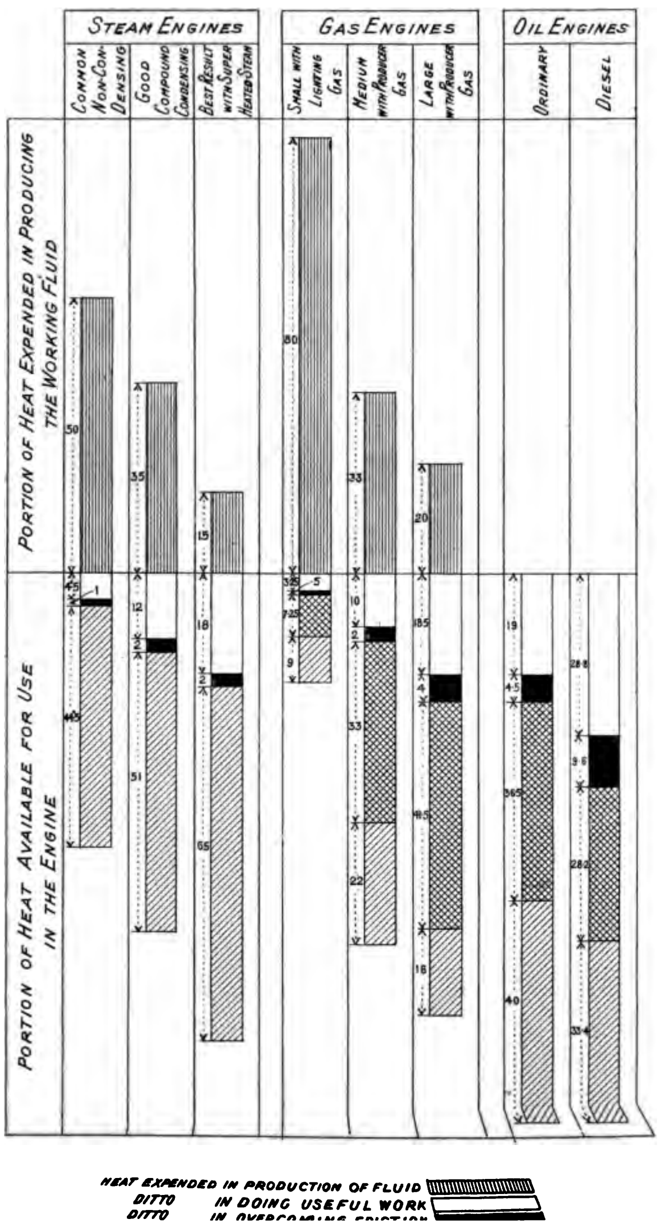


Fig. No. 11.

— Fig. No. 12. —

Expenditure in Percentage of the Total Heating Power of the Fuel in Different Heat Engines



Mr. Axel Sahlin's Paper on "The Modern Continuous Rolling Mill."

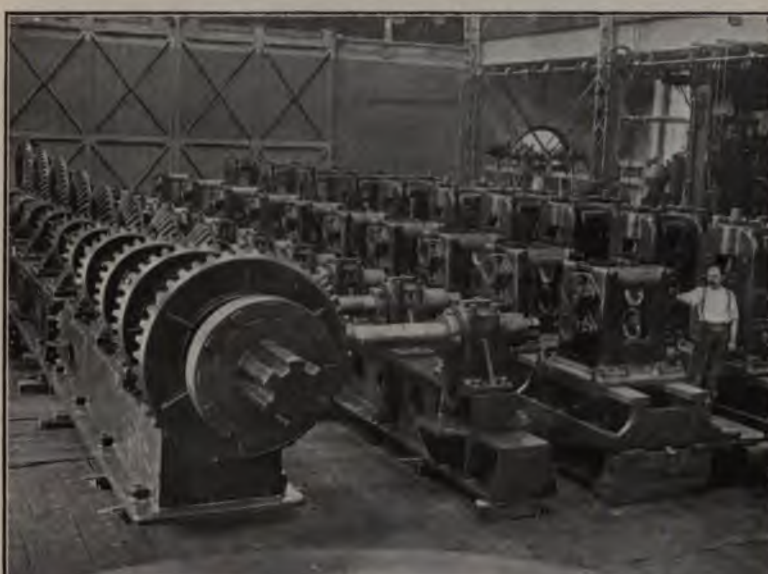
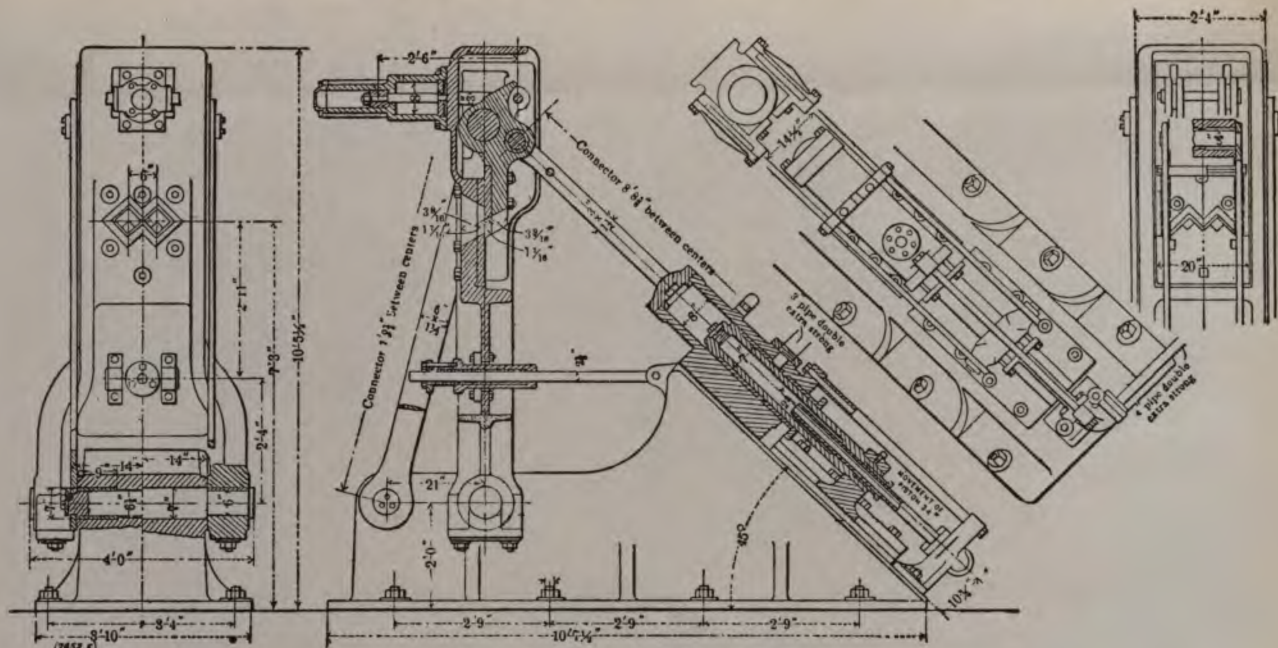


FIG. 1.

General Arrangement of Continuous Billet Mill.

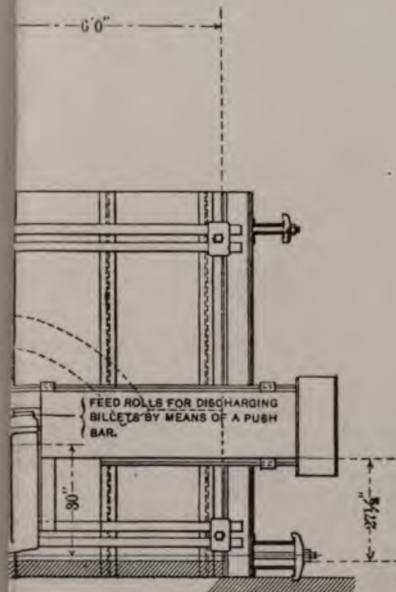


STANDARD TYPE OF FLYING SHEAR.

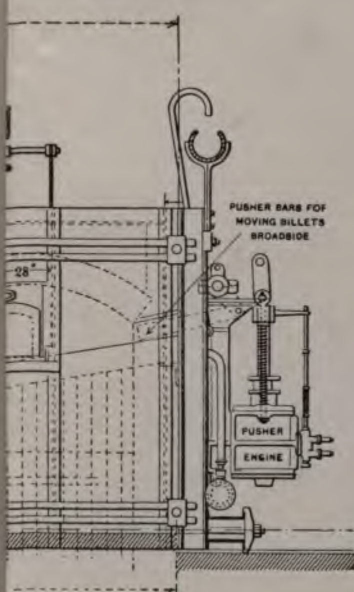
FIG. 2.

PROCEEDINGS STAFFS. I. & S. INST.
SESSION 1902—1903.

s Rolling Mill."



30-FT. LONG, 10-INCH MILL.



0-FT. BILLETS.

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FIG. 5.—Section of Furnace and Gas Producer.

FIG. 6.—Wickwire Bros. Rod Mill, Cortlands, N.Y. Exterior View.

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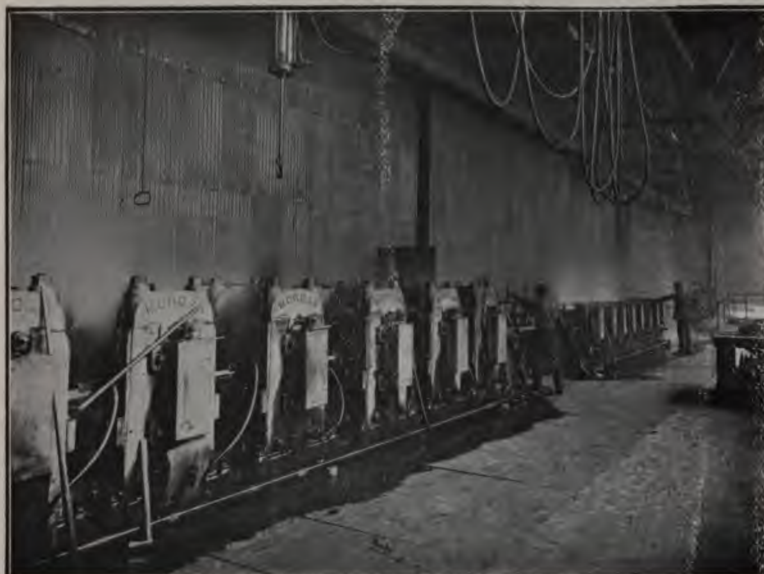

FIG. 7.—Morgan Continuous Rod Mill. Roughing End.

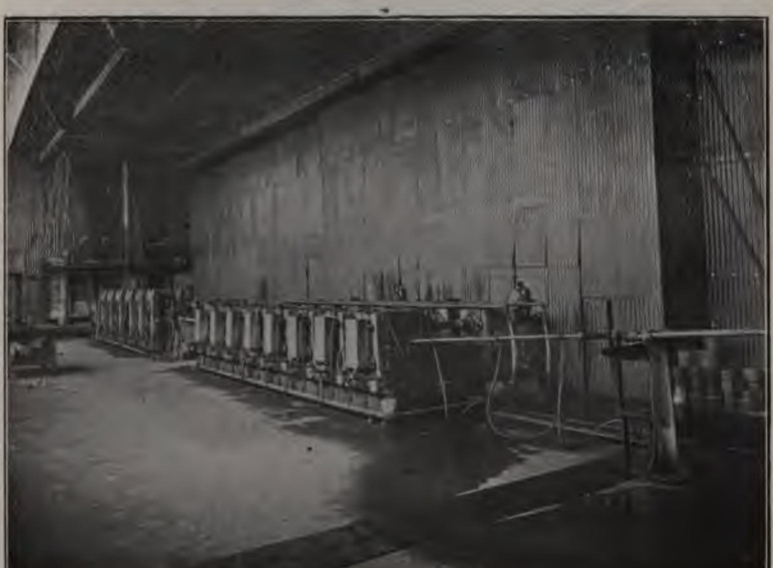

FIG. 8.—Morgan Continuous Rod Mill. Finishing End.

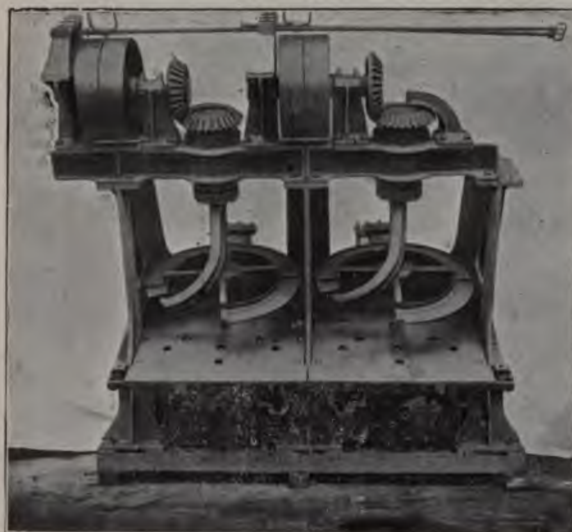

FIG. 9.—Stationary Laying Reel.

FIG. 10.—Wire Truck Loaded.

FIG. 11.—Wire Truck. Showing method of handling Wire Rods.

FIG. 12.—Continuous Hoop Mill. Table Conveyor.

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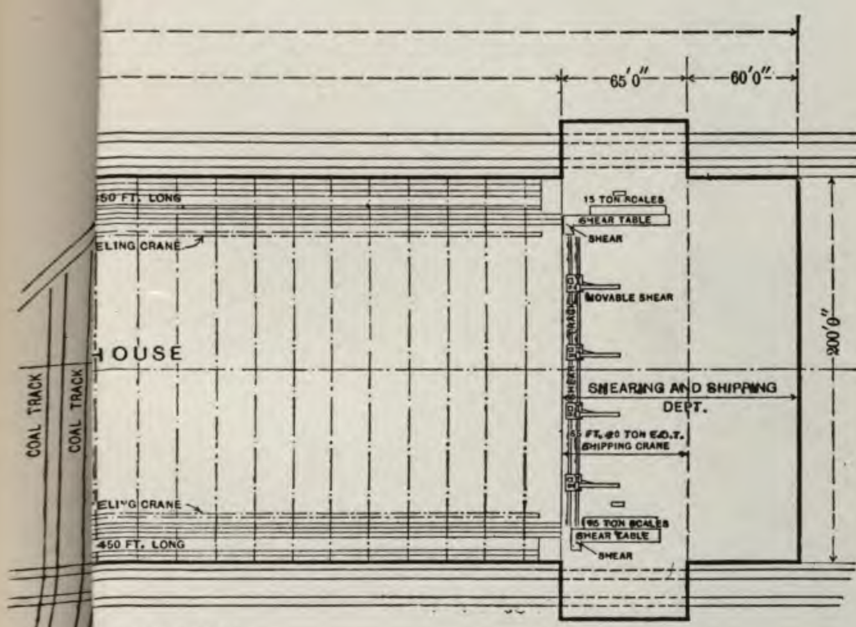
FIG. 13.

General View of Merchant Mills of Carnegie Steel Co., Duquesne, Pa.

ıous Rolling Mill."



ɛ STEEL WORKS.

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FIG. 15.—13in. Continuous Bar Mill, Duquesne Steel Works.

FIG. 16.—Edwards' Continuous Gravity Cooling Bed, 450ft. long.

FIG. 17.—Bar Shear, Weighbridge, and Bundling Arrangements.

FIG. 18.—Bar Storage, 350ft. long.

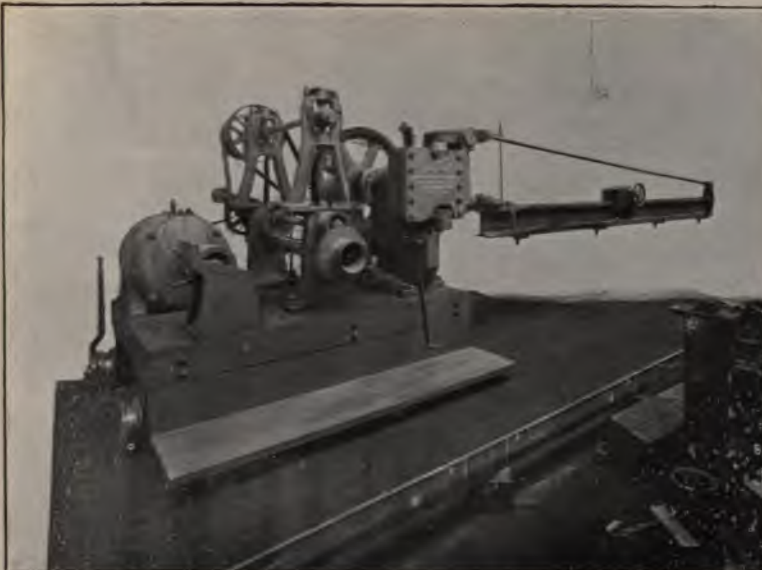

FIG. 19.—Travelling Shear for Cutting from Storage.

FIG. 20.—Car Load of Merchant Bars.